PREPARING FOR MOLYBDENUM-99 PRODUCTION IN MALAYSIA

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ABSTRACT

The research reactor at Nuclear Malaysia, which has been in operation since June 1982, has a maximum flux of $1x10^{13}$ n/cm^2/s at its central position, has been utilized in production of neutron activated molybdenum-99 (^{99}Mo) and may be suitable for the new initiative for producing fission ^{99}Mo from low enriched uranium (LEU) targets if an upgrade involving its power and neutron flux were done. Currently, there is no fission ^{99}Mo production in place in Malaysia; however, there is an existing weekly ^{99}Mo/^{99m}Tc generator production utilizing imported fission ^{99}Mo. Malaysia's current demand for fission ^{99}Mo is relatively small but is still affected by the recent supply turmoil. At the request of the Malaysia Nuclear Agency, the IAEA organized a fact-finding mission to assess currently available infrastructure against that necessary to produce fission ^{99}Mo sufficient for domestic needs or additionally to contribute to regional fission ^{99}Mo supply security. During the mission, ^{99}Mo production from LEU and the alternative neutron activation method were considered. Taking into consideration sufficient upgrade of the current research reactor power and neutron flux, neutron activation could satisfy current national demand but offers little excess capacity to accommodate future growth or participation in the regional ^{99}Mo market. Also at a higher reactor power and neutron flux, LEU fission based technologies could produce adequate quantities for domestic and regional supply, but require significantly greater resource commitment than neutron activation production technologies particularly with respect to the management and ultimate disposition of all waste streams. In addition to the completion of the reactor power and flux upgrade, revising the operating mode to continuous operation is a prerequisite to fission ^{99}Mo production together with additional equipment for handling and transferring higher radiation dose target capsules from the reactor to the hot-cell and processing facility. However, in case the current situation remains then additional alternative supply arrangement for ^{99}Mo will be necessary in order to ensure security of local ^{99}Mo supply. In additional to this mission from the IAEA, a team from Gamma-Service Group International (GSG) also assessed the facilities in Malaysia and provided a proposal based on its technology for establishing a local production facility for fission ^{99}Mo using LEU within the confines of existing available space subject to similar research reactor power and neutron flux upgrade.

1. INTRODUCTION

The Malaysian Nuclear Agency (Nuclear Malaysia) was established in 1972. However, its infrastructural development on the 27 hectares at Bangi commenced only in 1979, with the highlight in June 1982 with the commissioning of the criticality of its nuclear research reactor. As a national research institute, Research and Development (R&D) is the core business of Nuclear Malaysia and R&D activities are focused on the fields of industrial technology, radiation processing technology, agro-technology and biosciences, radiation and environment safety and medical technology. Nuclear Malaysia is also involved in commercialization and technology transfer. Technology commercialization activities are accomplished by 25 service centers through technical and consultation services carried out in Nuclear Malaysia or on-site, training and supply of products. The products include radiation vulcanized natural rubber latex, mutants of ornamental and fruit plants, and radiopharmaceuticals and radioisotopes. The Medical Technology Division concerns research activities and application of nuclear technologies in medical and related fields. This division is also responsible for the manufacture and supply of ^{99m}Tc generators for use in nuclear medicine applications. This weekly ^{99}Mo/^{99m}Tc generator production utilizes imported fission ^{99}Mo; however, even though the amount of weekly fission ^{99}Mo demand is relatively small it is still subject to the recent difficulties in obtaining ^{99}Mo supply. The research reactor at Nuclear Malaysia which has been in operation since June 1982, has a maximum flux of $1x10^{13}$ n/cm^2/s at its central position, has been utilized in production of neutron activated ^{99}Mo and may be suitable for the new initiative for producing fission ^{99}Mo from LEU target if an upgrade involving its power and neutron flux were done. This fact and an initial study into upgrading the research reactor power and flux prompted the idea of looking into the possibility of producing fission ^{99}Mo in the future to ensure security of fission ^{99}Mo supply as part of the justification for such a reactor power upgrade and thus eventually joining this CRP.

Nuclear Malaysia joined the CRP towards the end of 2010 and attended the CRP meeting in Chile, as part of the objective of joining the CRP was to assess our capability and establish the requirements for indigenous production of fission ^{99}Mo from LEU. We recognize from the meeting in Chile that even though there is significant information available it would require a significant amount of effort and time for us retrieve and carry out the assessment on our own effort. However, we were fortunate that the IAEA agreed to set up a team for this assessment within a short time and this mission was carried out from 11-14 January 2011. The team comprised of Mr. Edward Bradley from the Research Reactor Section/NEFW of the IAEA, Mr. Geoff Parsons from Waste Operations, ANSTO, Australia, Mrs. Saraswathy Padmanabhan from the Board of Radiation & Isotope Technology (BRIT), Department of Atomic Energy, India, Mr. Jack Rottier as an Independent consultant, from the Netherlands and Mr. Seeram Ramakrishna as an observer from Research and Strategy, National University of Singapore.

1.1. ASSESSMENT

At the request of Nuclear Malaysia, the IAEA organized a fact-finding mission to assess currently available infrastructure against that necessary to produce ^{99}Mo sufficient for domestic needs and additionally to contribute to regional ^{99}Mo supply security. Two modes of production were assessed; neutron activation and LEU target fission. The mission took place from 11-14 January, 2011 and consisted of group meetings, facility tours, document reviews and one-on-one discussion with Nuclear Malaysia counterparts. The review considered all areas of production, including irradiation and handling of targets at the reactor, processing, generator production, materials handling, and waste management equipment and facilities. A general “business readiness” assessment was also within the scope.

1.2. REPORT

The full report of this mission is available from the IAEA as referenced and the following is an extract from the report.

The mission found that since commencing operation in 1982, the existing TRIGA reactor was utilized for neutron activation based ^{99}Mo production in the early 1990s. Experience from this effort remains within the organization and there is also relevant experience from the ongoing production of technetium-99m (^{99m}Tc) generators, the diagnostic isotope of interest, from bulk fission ^{99}Mo imported into Malaysia.

With respect to options to secure ^{99}Mo supplies in the future, the mission team found that Malaysia's current demand is very near a break-point. At this level and provided plans to upgrade the TRIGA reactor's power and flux level come to fruition, indigenous ^{99}Mo production is possible. Initial theoretical calculations appear reasonable to assume that neutron flux of 1x1014n/cm2/s is achievable. Based on this consideration, the ability to exploit epithermal neutrons for irradiating targets, with uninterrupted irradiations for 5-6 days, a specific activity achievable could be of the order of 1 Ci (37GBq)/g Mo at End of Bombardment (EOB) using molybdenum trioxide (natural Mo) targets encapsulated in cold welded aluminum capsules for irradiation. Irradiation space available is adequate for ~50 g Mo (80gMoO_3) and would result in ~50 Ci (1.85TBq) Mo EOB and ~23 Ci (850GBq) on calibration day (3d EOB). Neutron activation could satisfy national demand but offers little excess capacity to accommodate future growth or participation in the regional ^{99}Mo market.

Also at a higher reactor power and neutron flux, LEU fission based technologies could produce adequate quantities for domestic and regional supply, but require significantly greater resource commitment than neutron activation production technologies particularly with respect to the management and ultimate disposition of all waste streams. At least 3 new hot cells are needed with ancillary ventilation and gas handling equipment. The existing room identified with extension of the space may potentially serve to accommodate the new hot cells. The ^{99}Mo processing hot cells would have to be designed to accommodate the processing equipment, temporary waste storage and provide adequate shielding. All safety and security requirements (dose/shielding; material and chemical handling; criticality control; personnel access; and material accountability/safeguards) must be incorporated in the existing management procedures. Long term contracts for fuel, targets, chemicals, filters, stainless steel transport vials etc. must be in place. A transport system or transport containers must be available to bring the irradiated targets from within the reactor pool to the exterior and on to the ^{99}Mo processing plant. This system must be compatible with the processing hot cells. Final product containers (Type B(U) or Type A) must be available and certified in the countries where these containers will be used. For transport of the final product into the region, contracts with road and air transport carriers must in place to have a reliable supply chain. Management and order processing and all related planning will have to be incorporated into the current organization. In addition to completion of the reactor power and flux upgrade, revising the operating mode to continuous operation is a prerequisite to fission ^{99}Mo production.

In addition, a review of a "do nothing" scenario was completed where non-production options, leading to increased security of supply, were considered. If Malaysia does not opt for any mode of ^{99}Mo production, diversifying its supply chain with alternative or additional suppliers could reduce the risk of undersupply during global supply crises that may occur in the future. Supply diversification could also ensure backup supply availability if production is pursued.

2. CONCLUSIONS

The current research reactor has a relatively low neutron flux and has been and is still in operation since 1982. There is substantial experience and equipment to handle regular targets such as the neutron activated ^{99}Mo. These and the fact that there is an existing weekly $^{99}Mo/^{99m}Tc$ generator production utilizing imported fission ^{99}Mo, thus an existing demand for weekly supply of ^{99}Mo. The current situation exposes Malaysia to risk should future ^{99}Mo supply return to be problematic. However, even to accommodate the local demand for ^{99}Mo via neutron activation would require a power upgrade for it to be viable with existing technologies. The experiences in weekly GMP certified fission ^{99}Mo/^{99m}Tc generator production adopting and running an established neutron activated ^{99}Mo/^{99m}Tc generator production facility will not be a major exercise. There have been studies performed on plans to upgrade the current research reactor power and neutron flux and should this power upgrade and flux increment of the current research reactor materialize then this also opens the opportunity for participation in regional supply of ^{99}Mo from possible domestic fission ^{99}Mo production from LEU as part of the justification of the reactor power upgrade.

Currently, there is no fission ^{99}Mo production in place in Malaysia and we have not had any experience in irradiation and handling of uranium targets and we recognize that further detailed insights into the handling of uranium targets are required. In view of the facts available it could be summarized that should the reactor upgrade proceed appropriately, then in terms of target procurement and handling it will possible to be done within a reasonable time frame. The processing facility and handling of waste will also be possible to establish with appropriate linkages and assistance possibly with substantial cost. However, the management of the waste stream will require substantial effort on our part with respect to Malaysia's current radioactive waste capability and policy.

This CRP has significantly contributed to our quick knowledge upgrade on the requirements for fission ^{99}Mo production from LEU, to the quick assessment of where we stand and our shortcomings in this technology and the linkages has highlighted the various commercial supplier available. This would certainly have required a significant amount of time and effort on our part without participation in this CRP, the IAEA assessment mission and the proposal from GSG International GmbH. The reactor power upgrade is being carried out in stages and currently work is being done on replacing the control console with a new digital system utilizing international established expertise. The total reactor power upgrade will take substantial time and in our effort to maintain our integrity in ^{99m}Tc requirement we are participating in accelerator-based alternative for ^{99m}Tc production whilst on longer terms keeping the option for ^{99}Mo production from LEU open.

REFERENCES

[1] Molybdenum-99 Production Infrastructure and Capability Assessment Mission Nuclear Malaysia (653-T1-11CT01515).