International Atomic Energy Agency

^{99}Mo Production and Availability: Status and Trends

Presented by N. Ramamoorthy
Manager – Nuclear Science Programme and Director-NAPC

Based on inputs of RRG/NEFW and NAPC

TWG-RR Meeting, February 9-11, 2009

^{99}Mo Production and the IAEA Background Information

- ^{99m}Tc: >25 million studies/year; 75-80% of diagnostic imaging; **IAEA support to MS** for indigenous capability: ^{99}Mo-^{99m}Tc **generators, medical applications**
- ^{99}Mo requirements: ~450000 GBq (12000Ci, '6-day curies'); >95% ^{99}Mo produced using HEU targets (40-50 kg/year)
- Efforts to shift production of medical isotopes away from use of HEU (through RERTR, GTRI); RERTR-2004 and Consultants Meeting in Vienna in November 2004 →
- Some MS of the IAEA are seeking to become small scale, indigenous producers of ^{99}Mo
- Need to encourage and provide access to LEU technology or neutron activation (NA) methods as HEU is phased out from commercial use

^{99}Mo Production Methods

- **^{235}U (n, fission) → *fission moly*** *(Gold Standard)*

  Target: HEU, LEU; 6.1% fission yield
- **Neutron activation of ^{98}Mo → *(n,γ) moly***

  Target: natural MoO_3, enriched ^{98}Mo. σ 0.13b+n_{epi}
- Szilard-Chalmers process for high sp acty ^{99}Mo: Reactor Institute, Delft/NL patent on new Mo compound target; performance to be tested under high 'n' flux (quantity ?)
- Photo-fission of ^{238}U - Canadian Task Force Study Report: High power accelerators - Feasibility R&D

The IAEA CRP on ^{99}Mo production using LEU or neutron activation, 2005-2010

- **Developing techniques for small scale indigenous Mo-99 production using LEU fission or neutron activation**
- 14 participant teams; EB funds from NNSA-DOE; NTI

Objectives

- Assist member states with adoption of LEU Cintichem (foil targets) or neutron activation (gel moly) technology.
- Further demonstrate efficacy of LEU production of ^{99}Mo
- Foster capacity building for local/regional self-sufficiency to meet ^{99}Mo needs

  - *Not Aimed*: Engaging the large-scale industrial producers (but some are participating/contributing)

The IAEA CRP Perspectives

- Several groups in the CRP will advance to deploying or adapting ^{99}Mo production using LEU
- Objective findings on several related aspects and requirements
- Significant role of **MURR, USA**, to establish LEU moly compliance as API for ^{99m}Tc generators
- **Chile, Indonesia, Pakistan** & **Poland** already handling generator production → well-suited to launch local production of ^{99}Mo with LEU targets
- Two groups - **India, Kazakhstan** - to establish scale of applicability of gel moly system

Recent events of major disruptions in production and supplies of ^{99}Mo

- RR shut-down prolongations - Fall 2007 in NRU, Canada; since summer 2008 in HFR/Petten, Europe; others, including a radiological event in August 2008 at IRE, Fleurus, Belgium
- MAPLE reactors project termination in May 2008
- Reschedule in ANSTO entry as a new supplier

Clear signals of vulnerability of a fragile supply chain → end medical users (and generator producers) turning to be the drivers

Recent Events: Follow-up Actions

- Canadian Task Force meeting in November 2008 on using accelerator route (Report available; also a note in Nature)
- NAS Study Report on LEU Feasibility released on January 14, 2009; extensive findings and recommendations
- ASN-led regulators meeting in Paris, January 2009
- OECD-NEA Workshop in Paris, January 29-30, 2009; organised at the request of Govt of Canada
- Side Event during **EANM 2008** in Munich: IAEA briefing - on-going activities, possible role
- ^{99}Mo supply problems cited in ***Nuclear Technology Review 2009***, IAEA Board Meeting, March 2009

Impact of Recent Disruptions in ^{99}Mo Production/Availability on the IAEA CRP

- Greater interest among industries; over 20 observers at 3rd RCM in MURR, Oct 2008
- Increased scope for a few CRP participants to offer services/partnership; Reactors and/or Process Facilities; geographic merits
- Developments in some participant countries, e.g. **Egypt** (+ INVAP), **Pakistan** (+ ITD) → additional sources for availing fission moly

Observations from OECD-NEA Workshop

- Most stakeholders in attendance; IAEA contributions; Chair's Summary widely being distributed
- Focus only on current major reactors and producers
- Differing views on LEU targets, conversion issue
- Lack of recognition to new capacity at ANSTO
- Scope to use and enhance existing production capacity in Argentina and Indonesia ignored
- Scope for partnering with facilities being set-up (e.g. in Egypt) and/or encouraging well-qualified potential sources (e.g. Poland, Romania) did not attract attention

Observations from OECD-NEA Workshop

- Emphasis on much more effective use of ^{99m}Tc generator capacity as well as of all ^{99}Mo produced → Merits in promoting central radiopharmacies (CRPh)
- Japan and ROK cite revived interest in n, gamma route
- Continuing problems of transport and denials of shipments need to be addressed, especially in the time of crisis and shortages
- Inadequate financial incentives for RR managers and ^{99}Mo industries – cf. generator producers, cost of medical services
- Regulators concerns - safety issues more critical than seeking to balance with healthcare services to patients

Research Reactor Coalitions (RRC)

- *Central Asian (CA) and Eastern European (EE) Region*: Kazakhstan, Uzbekistan, Ukraine, Czech Republic, Hungary, Poland, Romania …….
- **Fostering entrepreneurial initiatives**: e.g. enriched ^{98}Mo used in 2 X 10^{14} n/cm^2/s flux for alumina column generator in Uzbekistan
- Well-distributed production centres → Geographic logistics for transport → Greater use of 'produced ^{99}Mo', i.e. move from '6-day Ci' to say '3-4 day Ci'

http://www.iaea.org/OurWork/ST/NE/NEFW/rrg_EARRC.html

http://www.iaea.org/OurWork/ST/NE/NEFW/rrg_EERRI.html

Zirconium Molybdate – ^{99}Mo Gel (ZMG)
'Gel Moly' Generator Status

- ^{99}Mo as component of ZMG column matrix, 25-30% Mo; suits (n,γ)^{99}Mo; generator capacity linked to ^{99}Mo specific activity; 6 g ZMG → ~2 g Mo
- **India** - Mumbai: 2 batches per month (each upto 925 GBq). ~15% of ^{99m}Tc needs; 2007-08: 50 lots, 500 generators
- **Kazakhstan** - Almaty: ^{99} Mo sp acty upto 41.4 GBq/g; ZMG for centralised distribution of ^{99m}Tc; portable generator development underway
- ***China*** *- Chengdu: ~25% of ^{99m}Tc needs*
- *Others: Brazil, Egypt, Romania, …*

Key Requirements for Gel Moly Development and Adaptation

- $(n,\gamma)^{99}Mo$ of specific activity of over 20 GBq/g, preferably over 30 GBq/g;
  RR flux dependent
- Process equipment and related aids to handle several hundred grams of gel moly;
  industry support
- Enhancing radiological safety features for large mass gel moly powder handling;
  industry support
- *Applicability: can meet 50-100 Ci needs*

Other Alternative Approaches

- Revisit $^{98}Mo(n,\gamma)^{99}Mo$ option: Japan, 20% by 2013 in JMTR; ROK, 5% by 2012(?) in HANARO
- Enriched ^{98}Mo target for $(n,\gamma)^{99}Mo$ for use in alumina column generator: RR coalition interest; support of non-proliferation bodies envisaged
- Support to technology development for enriched ^{98}Mo as well as for recovery of enriched ^{98}Mo from spent generators for recycling
- CRPh approach relevant to logistics in retrieval of spent generators and recovery of enriched ^{98}Mo

Alternative Approaches

- High affinity adsorbents of Mo for use with $(n,\gamma)^{99}Mo$ (cf. alumina); PZC – polymeric zirconium compound in Japan, also under FNCA; Poly titanium oxychloride in Australia, India
- Aqueous Homogeneous Reactors (AHR): LEU salt solution as fuel; separation and purification of ^{99}Mo from AHR fuel; off-line processing; BWXT Medical Isotope Production System, *Tie-up with Covidien;* New CRP for Feasibility Evaluation, 2008-2012
- TRIUMF, Canada: Photo fission of ^{238}U in high power accelerators → need feasibility R&D, resources

Enhancing Security of ^{99}Mo Supplies: Challenges, Requirements and Options

- Much **higher redundancy** and better **geographic distribution** necessary, both reactor irradiations and processing facility, to satisfy all medical needs
- Enhancing back-up (*buffer*) production capacity of existing producers, large and not-so-large (e.g. **Argentina, Indonesia**), to the maximum extent
- Fostering reactor coalitions and encouraging additional producers located near usable reactors; identify potential sources → **Egypt**, Poland, …

Enhancing Security of ^{99}Mo Supplies: Challenges, Requirements and Options

- Strengthening of networking among major producers and reactor managers
- Partnerships, joint ventures, or other commercial arrangements needed to further develop potential alternative producers
- Need for international/regional cooperation → '***going beyond corporate competition'***
- *The IAEA role as 'Global Facilitator': to bring together stakeholders for objective analysis and consider all options for path forward*

Radioisotopes
Fountainhead of Nuclear Applications

Thank you all for your attention

n.ramamoorthy@iaea.org