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Transportation of Radioactive Materials in Jordan
Outline

- Introduction
- Nuclear facilities in Jordan
- Storage facilities in Jordan
- Spent fuel management practice
- National Centralized Storage Facility (CSF)
- Radioactive Waste Treatment Facility (RWTF)
- Regulations of RMT by EMRC
Nuclear Facilities in Jordan

Jordan Subcritical Assembly (JSA)

- Jordan's first Nuclear facility.
- Designed and constructed for the purpose of education, training, and experimental research.
- Inherently safe

Design Specifications:

- Uranium Fuelled (3.4% U-235)
- Uranium Oxide (UO₂) with Zr-4 cladding
- Light Water Moderated
- Sub-critical State ($k_{eff} \approx 0.95$)

Comissioned in June 2013
Overview:
- 5-MW upgradeable to 10-MW
- Open pool
- MTR, plate type fuel (<20% U\textsuperscript{235})
- H\textsubscript{2}O cooled
- D\textsubscript{2}O + Be reflected

Applications
- Neutron Beam Applications
- Radioisotope Production
- Neutron Transmutation Doping
- Neutron Activation Analysis
- Plays the primary role in educating and training the upcoming generations of nuclear engineers and scientists
- Irradiation in support of industrial, agricultural and health/medical infrastructure

Officially inaugurated on 7 December 2016
Introduction

The transport of Radioactive Materials (RM) embraces the carriage of radioisotopes for
- industrial
- medical
- research uses
- as well as the shipment of Radioactive Waste (RW), and consignments of Nuclear Fuel Cycle (NFC) material.
The national regulatory authority in Jordan, EMRC, has established a set of necessary legal framework in the field of Radioactive Materials Transportation (RMT).

**National:**

laws, regulations, instructions and guidelines for nationally transporting RM from the local customer back to the National Centralized Storage Facility (CSF) located at Jordan Atomic Energy Commission (JAEC).

**International:**

principles, regulations, and recommendations by the International Atomic Energy Agency (IAEA) for internationally transporting the RM to be shipped abroad by any means of transport (sea, land, air) back to the supplier (or country of origin, or manufacturer) for recycling or final disposal.
Storage facilities in Jordan

Current

- National Centralized Storage Facility (CSF) at JAEC

Upcoming

- Treatment and Storage Facility for radioactive waste, RW, generated from JRTR.
At the end of each operation cycle, in which core loading activities are to take place, one fuel assembly is discharged to the spent nuclear fuel pool (reactor service pool).

The reactor service pool is designed and constructed for safe storage of SNF assemblies.

sized-sufficiently to store all SNF assemblies produced from JRTR operations during its entire lifetime (»40 years).

have a current storage capacity for 222 SNF assemblies and 10 damaged fuel assemblies.

Additional storage racks can be added to accommodate additional assemblies if the need arises.
CSF is currently the only operating radioactive waste management facility in Jordan.

The CSF is located within JAEC headquarters.

It has an area of 250 m².

CSF is licensed by EMRC.

CSF staff are licensed by EMRC, and they are qualified to manage RW of the CSF.

The main building (Dirty area) is designed to have several stores: receipt/dispatch store, operational store for sources to be conditioned, underground stainless steel wells decay store and stores for high, intermediate and low activity sources.

• The second building (Clean area) houses support facilities (change room, shower (bathroom)/ and wash room, sanitary room, radiation equipment and health physics room, office room, documentation and security monitoring room.
Arrangement of underground SS drums
RWM Predisposal

The implemented procedures for the safe management of radioactive waste at the CSF as:

- **Receipt from waste generators**
  - Pretreatment
    - Collection
    - Segregation
    - Decommissioning
  - Characterization
    - Radionuclide Activity
    - Dose Rate
    - Physical state
    - Contamination
    - Size & Weight
    - Heat Generation
    - Gas Generation

- **Classification**
  - Clearance waste
  - Very short level waste
  - Very low level waste
  - Low level waste
  - Intermediate level waste
  - High level waste

- **Treatment**
  - Volume Reduction
  - Radionuclide Removal
  - Change composition
  - Conditioning
    - Immobilization
    - Packaging

- **Handling**
  - Leakage (Smear) Test
  - Transportation

- **Storage**
  - Delay & decay
  - Interim storage
  - Long term storage

- **Disposal**
  - Engineered Landfill
  - Near surface
  - Deep geological
Storage

Drum Cementation
Security system at CSF
Air Ventilation System in the CSF
Radioactive Waste Treatment Facility (RWTF)

- The RTF is situated in the southern area of the JRTR site.

- Main roles of RTF are classified as follows:
  - To receive, handle and sort the target RW to be treated
  - To process the liquid and solid RW generated from JRTR together with additional RW from other sites and monitor the effluents
  - To store the conditioned RW package as interim storage in site. Current storage capacity is 8 years of full JRTR operation.

- RTF comprises 2 buildings
  - RTB (RW Treatment Building): Receiving, processing and interim storage of RW.
  - NEI (Natural Evaporation Installation): Final stage of treated liquid waste for release to the environment.
Radioactive Waste Management at the RWTF

Liquid Radioactive Waste Treatment System (LRTS)

- The LRTS is designed to collect, store, process, sample, and monitor LRW generated from the JRTR and the RTF.
  - Liquid radioactive waste is pumped from the JRTR sumps to the RTF sumps quarterly.
  - Liquid radioactive waste not satisfying release limits must process through the evaporation system.
  - Once processed, the resulting effluents are collected at monitoring tank.
  - Liquid effluents is discharged to Natural Evaporation Installation NEI.
  - Beyond the release limit, liquid will be back through LRTS for additional Processing.

- The LRTS consists of:
  - VLL sump, LL sump, sump pumps, evaporation package, monitoring tanks, monitoring pumps, NEI, appropriate instrumentation and controls for the system operation
Simplified Flow Outline of LRTS

- Very Low Level Radwaste: Transfer by Pumping to sumps → Solar Evaporation (NEI) → Air discharge
- Low Level Liquid Radwaste: Transfer by Pumping to sumps → Evaporation/Condensation/Ion exchanging → Residue → Conditioning (CSS) → Interim storage → Licensed disposal
The evaporator package is designed to process the LL and VLL liquid RW and reduce the radioactive liquid volume by evaporation process. In which, the process generates a purified liquid that is safe to be released to the environment, and a concentrated radioactive liquid ready to be solidified.

The evaporator package processes the liquid RW at a minimum of 65 L/hr.

The concentrates are removed periodically from the vapor body and pumped to the concentrate tank. Once filled, a tank is isolated from the upstream process system. The tank contents are then sampled, treated with chemicals to ensure compatibility with solidification agents, and transferred to the cement solidification system.

The treated and safe to release liquid is sent to the NEI for discharging to the environment.
Natural evaporation installation
The SRTS is designed to collect, segregate, store, and process the solid RW generated from the JRTR Basic processing methods for solid radioactive waste may be applied as follows: size reduction, cutting and dismantling, decontamination compaction and conditioning.

The SRTS is divided into the following subsystems:

- compaction subsystem.
- Cement Solidification System (CSS).
- Decontamination equipment.
- Sorting box.
Simplified Flow Outline of SRTS

1. Low Level Radwaste
   - Transport/Collection/Sorting
   - Decontamination
   - Recycle or Reuse
   - Interim storage
   - Licensed disposal
   - Low level

2. Medium Level Radwaste
   - Transport/Collection/Sorting
   - Conditioning
   - Package
   - License disposal
Cement Solidification package

Concentrated liquid radioactive waste from evaporation system of LRTS and the waste to be immobilized such as spent filters are solidified by cement solidification system.
Solid Radwaste Compactor

- The compactor system is used to reduce the volume of the dry active waste.
- The compactor system is designed to compact the compressible solid radwaste into 200L drum with a force of 30 ton as maximum.
Decontamination Equipment consists of Rinsing Bath.

Rinsing Bath is equipped with eight spray nozzles. The nozzles are spraying demineralized water (1~2 kg/cm²) to remove the residue.
This program applies to the transport of RM by all means of transport; land (road or rail), or air, or water.

To ensure the safe transport of RM through all the stages of RMT (or RW and/or radioactive sources, or equipment/devices or units containing radioactive sources (RS)) from the customer's premises to the CSF or for the transport of RM from one place to another within the Hashemite Kingdom of Jordan.

as well as during the international transport of RM/RS/RW.
SAFETY AND SECURITY REQUIREMENTS

SAFETY ASPECTS

EMRC regulations for the safe transport of RM have established safety and security provisions in terms of levels and limits which are based on IAEA Regulations and recommendations.

These limits and levels are identified through:

- Transportation Index (TI),
- Criticality Safety Index (CSI),
- Radiation dose rates at the external surface of the packages and overpacks,
- Transport vehicle,
- Control of contamination and leaking package,
- The activity limits for each type of package and overpacks,
- Determination of category of radiation signs,
- UN number, marking, labeling for each package and overpacks,
- Placarding for transport vehicle
Radiation hazard indicator

The radiation hazard indicator of the transported RM package shown, depends on both the TI and the surface radiation level of the package. In all modes of transportation, the limits and conditions shall be met for transporting RM packages.

Maximum values

below shows the maximum value of TI for the package/overpack of category III and the hazard levels depending on the category of the label assigned to the package/overpack.
SECURITY ASPECTS

Security measures for transport of RM:

- The transported RM shall be within its original shield enclosure or package or container that provided by the manufacturer.
- Additional shield transport container depending on the type of transported RS will be used.
- The overpacks will be used by using a closed wooden box.
- Additional physical barriers and tie downs will be used during transport.
- The vehicle has a lock system.
- All information (date of transport, the location of RM, technical specifications of RM and package, the route to be followed and No. and model of the vehicle), related to the RM to be transported will be submitted to the EMRC before starting the shipment of RM consignment and the EMRC approval will be issued accordingly in order to commence the transport of such shipment.
If any radiological accident or incident happened during transportation then either the security (contingency) plan or emergency response plan will be immediately activated and implemented, depending on the type of the radiological accident that happened.

If some accidents happened then we have to notify the EMRC with detail report within 24 hours, the civil defense and public security according to EMRC requirements.

Parking during transportation without direct guard will not be allowed, to practical extent, unless it is approved to be safe parking areas.

At the end of trip when final destination (CSF for RW) reached, all collected data and radiation measurements readings will be entered into the CSF collection Form (CSF-F-001) and sent to the EMRC.
GENERAL REQUIREMENTS

VEHICLE TO BE USED

- A licensed and authorized dedicated vehicle by the EMRC will be only used by CSF staff for transportation of the RM or RW or RS including DSRS from the local customer to the CSF at JAEC. This transport vehicle has to meet all the requirements described in the instruction issued by EMRC.

- The transport Packages must be kept away from the public areas and any other non-radiological dangerous material (i.e., toxic, chemical dangerous material).

- For transporting radiation sources of category 1-2, JAEC will coordinate with all the concerned national authorities (EMRC, public police, civil defense, etc.) to ensure required security escort in case of traffic jam or to cope with any accident that might happen according to the contingency plan or emergency response plan depending on the type of event happened during transportation.

- The vehicle is equipped with all necessary equipment, supplies and tools (i.e., radiation survey meters, shield container, firefighting equipment, radiation labels, marking and placarding, etc.) as required by the EMRC instruction.
LABELLING

The labelling of packages and overpacks is another important method for communicating the presence and potential hazard of RM. When CSF staff is planning to transport any RW or RM, then transport package must bear one of the radiation labels of either category:

- **I-WHITE,**
- or **II-YELLOW**
- or **III-YELLOW**
<table>
<thead>
<tr>
<th>Category Label</th>
<th>Surface Level</th>
<th>Radiation Level</th>
<th>Transport Index</th>
</tr>
</thead>
<tbody>
<tr>
<td>White-I</td>
<td>&lt;0.005 mSv/hr (0.5 mrem/hr)</td>
<td>TI = 0 (If the measured TI is &lt;0.05, the value may be considered to be 0.)</td>
<td></td>
</tr>
<tr>
<td>Yellow-II</td>
<td>&gt;0.005 mSv/hr but &lt;0.5 mSv/hr</td>
<td>TI &gt;0 but &lt;1</td>
<td></td>
</tr>
<tr>
<td>Yellow-III</td>
<td>&gt;0.5 mSv/hr but &lt;2 mSv/hr</td>
<td>TI &gt;1 and if &gt;10 exclusive use</td>
<td></td>
</tr>
</tbody>
</table>

Each package containing fissile material must be labeled with two FISSILE labels affixed adjacent to the RADIOACTIVE labels. The CSI is entered only on the FISSILE label.
The RADIOACTIVE and FISSILE labels must contain the following information entered using a durable, weather-resistant means:

- The names of the radionuclides in the package.
- The activity in the package expressed in SI units (e.g., Bq, TBq). The weight in g or kg of fissile radionuclides may be inserted instead of the activity units.
- The TI is entered only on RADIOACTIVE YELLOW-II and RADIOACTIVE YELLOW-III.
MARKING

Each package must be legibly and durably marked on the outside of the packaging with an identification of either the consignor or consignee, or both.

The UN ID number, proper shipping name, the addresses of the consignor or consignee, gross weight of the package, type of package, the trefoil symbol outer packaging, as appropriate as shown in Figure below.
<table>
<thead>
<tr>
<th>UN Number</th>
<th>Shipping Name/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2908</td>
<td>Radioactive material, excepted package-empty packaging</td>
</tr>
<tr>
<td>2909</td>
<td>Radioactive material, excepted package-articles manufactured from natural uranium or depleted uranium or natural thorium</td>
</tr>
<tr>
<td>2910</td>
<td>Radioactive material, excepted package-limited quantity of material</td>
</tr>
<tr>
<td>2911</td>
<td>Radioactive material, excepted package-instruments or articles</td>
</tr>
<tr>
<td>3507</td>
<td>Uranium hexafluoride, radioactive material, excepted package, less than 0.1 kg per package, non-fissile or fissile-excepted</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>UN Number</th>
<th>Shipping Name/Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2912</td>
<td>Radioactive material, low specific activity (LSA-I) non fissile or fissile excepted</td>
</tr>
<tr>
<td>3321</td>
<td>Radioactive material, low specific activity (LSA-II) non fissile or fissile excepted</td>
</tr>
<tr>
<td>3322</td>
<td>Radioactive material, low specific activity (LSA-III) non fissile or fissile excepted</td>
</tr>
<tr>
<td>3324</td>
<td>Radioactive material, low specific activity (LSA-II), fissile</td>
</tr>
<tr>
<td>3325</td>
<td>Radioactive material, low specific activity (LSA-II), fissile</td>
</tr>
</tbody>
</table>
PLACARDING

When the CSF staff use the licensed vehicle for transporting a RM by road, then the placards shall be affixed on a vertical orientation to each side wall and to each end wall of vehicle,

The UN number shall be displayed during transportation: UN number placard, with assigned and appropriate number from Table above shall be used on the transport vehicle.
Vehicles transporting shipments of RM packages under the provisions of national and international regulations must be surveyed with the appropriate radiation detection instruments after each use.

Vehicle must not be returned to service until the external radiation on each accessible surface does not exceed 0.5 mrem/hr (0.005 mSv/hr).
Conclusions

- Jordan is newcomer to the nuclear industry.
- Therefore, we have no experience in the management of MOX and HBU fuel from power reactors including transport, storage and disposal.
- CSF is currently the only operating radioactive waste management facility in Jordan.
- At the end of this year the RWTF will serve to process the liquid and solid RW generated from JRTR together with additional RW from other sites and to store the conditioned RW package as interim storage in site.
Thank you