Radiation protection in industrial applications of radioactive sources: Prevention of Accidents in Gammagraphy

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Introduction: Why this subject?

- **Prone to accidents and leaving orphan sources**
  - Dominant usage in UNSCEAR list of accidents
  - Many instances of orphan sources
  - Radiation injuries and fatalities

- **Terminology**
  - Gammagraphy = gamma (\(\gamma\)) radiography
  - Industrial radiography = X- and \(\gamma\)-radiography
River Tyne, 1972
Contents

- Types of radiography and equipment
- Common causes of accidents
- Examples of serious accidents
- Mechanisms to learn lessons
- Roles of the different “Players”
- Emergency response
- Guidance material and training
Types of radiography (1)

Enclosure radiography

- Purpose built (?) shielded enclosure
  - “temporary” nature of some
  - Non-standard use
- Installed safety systems: warning lights and interlocks (?)
- Should be inherently safer: maintenance an issue
- Problems with open topped enclosures
Types of radiography (2)

**Mobile radiography**
- Within temporary barriers
- Portable warning and safety systems
- Adverse working conditions
- Often away from supervision
- Access control can be difficult
  - Multi-level
  - Need to liaise with site management and contractors
- Heavy reliance on procedures

*Inherently more Hazardous*
**X-Radiography**

- **Typically 100 to 300 kV and 3 to 15 mA**
  - Outputs 30 to 300 mGy.min\(^{-1}\) at 1 m
  - At 10 cm: 3 to 30 Gy.min\(^{-1}\)
  - Collimation

- **Need for automatic fail-safe safety and warning systems**

- **Integral part of design of enclosures**
  - Emergency stop buttons/ pull cords
  - Search and lock up

**Typical accidents from:**

- poor design and maintenance of safety systems
- Lack of awareness and poor procedures
Linear accelerators

- Typically up to 8 MeV
- Outputs $\sim 4 \text{ Gy.min}^{-1}$ at 1 m
- Specialist uses
- High quality (multiple redundancy) safety systems
- Higher degree of knowledge and training for operators
## Typical radiography sources

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Energy (MeV)</th>
<th>Source output at 1m (mGyh(^{-1}) per 37 GBq)</th>
<th>Half Life</th>
<th>Typical use for steel of thickness (mm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cobalt-60</td>
<td>1.17 and 1.33</td>
<td>13.0</td>
<td>5.3 y</td>
<td>50–120</td>
</tr>
<tr>
<td>Ir-192</td>
<td>0.2–1.4</td>
<td>4.8</td>
<td>74 d</td>
<td>10–70</td>
</tr>
<tr>
<td>Se-75</td>
<td>0.12–0.97</td>
<td>2.03</td>
<td>120 d</td>
<td>4–28</td>
</tr>
<tr>
<td>Yb-169</td>
<td>0.008–0.31</td>
<td>1.25</td>
<td>32 d</td>
<td>2.5–15</td>
</tr>
</tbody>
</table>
Radiation injury from Shutter type container
“Torch” type container

High cumulative doses due to proximity

Misuse leading to radiation burns to the fingers
Projection type / remote exposure containers
Projection type / remote exposure containers
Source “pigtail”
Commonest direct cause of accidents

FAILURE TO ADEQUATELY MONITOR
Typical radiation injuries
Effective Control

- Authorisation/licencing
- Purchase/installation
- Normal usage
- Increased risk modalities
- Challenging events
- Maintaining knowledge
- Disused sources
- Planned authorised disposal

Increased Risk of Loss of Control

- Illegal importation / acquisition
- Long term storage before use
- Poor training / safety / security
- Poor maintenance
  Use of mobile sources
- Fire, explosion, unexpected event
  Lack of emergency preparedness
- Loss of key staff
  Bankruptcy
- No clear future
  Disposal costs
  Dismantling of plant

Orphan sources
Root Causes

- Lack of, or ineffective
  - Regulatory body
  - Regulations
  - Regulatory enforcement
  - Radiation protection services
  - Training of workers and management
  - Commitment by management to safety
  - RP programme in the organisation
  - Co-operation between employers
Morocco 1984

- 1.1 TBq Ir-192 industrial radiography source

- Disconnected from drive cable and fell out
- Picked up and taken home
- Out of control March - June
- 8 died
- Initially diagnosed as poisoning
Cairo, Egypt 2000

1.85 TBq Ir-192 industrial radiography source

- Similar causes and scenario to Morocco accident
- Picked up by farmer
- Farmer and son died
Yanango, Peru 1999

- 1.37 TBq Ir-192: remote exposure container: source detached
- Picked up by welder and taken home
- Pain in right thigh: sought medical assistance
- Meanwhile wife sat on source in trousers
- Loss of source identified and its recovery within 24 hours
- Heroic medical treatment but lost one leg
Radiography accident in Cochabamba, Bolivia, 2002

- 670 GBq Iridium-192 source in remote exposure container
- Lone working in trench
- Failed to monitor after exposure
- Could not remove drive cable
Cochabamba: transport to La Paz
Cochabamba accident

- 55 passengers exposed for 8 h journey
- Source collected and recovered next day
- Delay in informing authorities
- Investigations by authorities and IAEA
Cochabamba: dose reconstruction

Passenger doses from reconstruction: 0.19 Gy

Worker doses from Chromosome Aberration Analysis: ~ 0.2 Gy
Learning the Lessons:
Feedback mechanisms

- **IAEA**
  - Accident investigation reports
  - Safety series No. 7
  - RADEV → Regulatory Authority Information System (RAIS)
  - INES

- **IRID, UK**  www.irid.org.uk
  - Fields to categorise and aid navigation
  - Descriptive field for use in training

- **RELIR, France:**  www.relir.cepn.asso.fr

- **European ALARA Network**
  - Newsletters and website www.eu-alara.net
  - Workshops – Rome, October 2001
    - NDT ALARA Network
Guidance Documents

• IAEA

• National Authorities
  – NRC: Industrial Radiography Toolkit
    www.nrc.gov/materials/miau/industrial-uses/rad-toolkit.html
  – HSE: Work with Ionising Radiations and ACOP
    www.hse.gov.uk/radiation/ionising/publications.htm
Roles: Regulators

Effective Regulatory Infrastructure

- Regulations adapted to national needs
- Appropriately resourced regulatory body (s)
- Appropriately trained regulators
- Enforcement programme
- Support of critical mass of RP infrastructure

Sets tone for compliance and safety culture
Qualified Experts

- Meets national qualification or certification criteria
- Often consultants not employee
- Management retain responsibility for compliance
- Major part of RP infrastructure
  - Range of clients, interface with regulators etc

Well placed to have positive influence on RP practices
Management

- Key responsibility
- Safety culture
  - Procedures, local rules, equipment, RP programmes
  - Risk assessments
  - Supervision, maintenance, reviews, investigations
- Training
- Co-operation with clients and others

Well managed operations are quickly apparent to regulators and crucial to RP compliance
Radiographers

- Appropriately trained
- Follow procedures
  - **MONITOR AFTER EACH EXPOSURE**
  - Personal alarm monitors: useful but an adjunct
- Ability to deal with problems on site
  - Recognition of problems
  - Pressure from clients and others
  - Emergency situations
- Report back issues to management

**Responsibility to work safely**
Clients

- Responsibility for those working on their sites
- Financial “muscle” and thus influence
- Co-ordination and co-operation of workforces
  - Permit to work schemes
  - Temporary source storage arrangements
- QEs can help clients “police” their sites
- Should feature in regulatory programme

Clients can be very influential on RP practices:
Use that influence
Emergency Preparedness

- Risk assessments
- Development of emergency plans
- Training to recognise an emergency and implement response
- Appropriate equipment
- Exercises and periodic reviews of plans
- Reporting and identification of lessons
Training

TRAINING,
INCLUDING REFRESHER TRAINING,
UNDERPINS
SAFETY IN INDUSTRIAL RADIOGRAPHY
AND
THE PREVENTION OF ACCIDENTS
IAEA Training Materials for Industrial Radiography

- **Radiation Protection in Industrial Radiography**
  - RPO, operators and managers
  - Lecture plan, lecture notes, module overview, practical exercises, PP presentations, other info
  - 1 to 2 weeks

- **Training for Regulators on Authorisation and Inspection**
  - Regulatory inspectors
  - 3 Parts
    - I: Organisation and implementation of National regulatory program for control of radioactive sources: 1 week
    - II: Authorisation and Inspection: 1 week
    - III: On the job training: 6 to 8 weeks
Conclusion

- Industrial radiography still provides significant potential for accidents
- Accidents continue to happen
- Means to prevent accidents are well documented

Needs appropriate regulatory infrastructure
And
Commitment of those involved