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Radiation Emergencies – Common Features

Exposure Pathways and Protective Actions

Lecture
Introduction

- A core melt event should be considered a serious threat to the public health and safety – an emergency requiring immediate response to protect the public.
- The objectives of this lecture are to present and discuss parameters important for effective protective action decision making in case of severe reactor accident.
Content

- Exposure pathways
- Urgent protective actions
- Effectiveness of protective actions
- Protective action strategy
- Summary
Objectives of Emergency Response

- Mitigate accident at its source
- Reduce risk of serious deterministic health effects (deaths)
  - Keep acute dose below health effects threshold
- Reasonably reduce risk of stochastic effects (cancers)
  - Do more good than harm by acting in accordance to international guidance
International Guidance (BSS)

- Take all action to keep dose below threshold for serious acute effects (2 day exposure)
  - Bone marrow - 1 Sv (deaths - critical for reactor)
  - Thyroid - 5 Sv
  - Foetus - 0.1 Sv

- Generic intervention levels (GIL) for urgent action
  - Averted dose (avoidable by the action)
  - Shelter 10 mSv in 2 days
  - Evacuation 50 mSv in 7 days
  - Iodine prophylaxis (thyroid blocking) 100 mSv
Release

Rain

Plume

Hot Spot
Human Exposure Pathways

- Plume
- Cloud shine
- Fresh produce
- Fresh milk
- Skin contamination
- Immediate ingestion
- Inhalation
- Shine from ground contamination (ground shine)
Reactor Emergencies

- Releases resulting in off-site health effects possible for
  - Severe damage to 100 MW(th) or larger core and fast – direct release
  - Build up of I-131 - continuous operation

- Release warranting evacuation (exceed GILs) or food restriction (exceed GALs)
  - Severe damage to > 2 MW(th) core

- Below 2 MW(th) on significant off-site release not possible unless there is significant
  - Spent fuel
  - Other inventories on site
Typical Assessment for Worst Accident

- Core melt 100 Mw(th) with early containment failure
  - no rain, average meteorological conditions

![Graph showing radiation levels vs distance]

- Early death possible (PAZ) about 0.5 km
- E(t) > 50 mSv (UPZ) beyond 10 km
### Types of Shelters and Effectiveness

<table>
<thead>
<tr>
<th></th>
<th>Normal</th>
<th>Substantial</th>
<th>Special</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Cloud Shine</strong></td>
<td>0.4 - 0.9</td>
<td>0.1 - 0.2</td>
<td>&gt; 0.001</td>
</tr>
<tr>
<td><strong>Ground Shine</strong></td>
<td>0.01 - 0.1</td>
<td>0.005 - 0.01</td>
<td>&gt; 0.0001</td>
</tr>
<tr>
<td><strong>Inhalation</strong></td>
<td>0.3 - 0.5</td>
<td>0.3 - 0.5</td>
<td>&gt; 0.001</td>
</tr>
</tbody>
</table>
PROBABILITY OF EXCEEDING EARLY DEATH THRESHOLD FOR SEVERE ACCIDENT

- Shelter in large building: 0.35
- Normal activity: 0.67
- Walk out in plume: 0.55
- Shelter in house basement: 0.66
- Walk out before release: 0.03

Distance: 1.5 km
Shelter vs Evaluation for a Reactor Accident

- Evacuation during a release (event in a plume) is better than or as good as
  - Normal shelter within 5 km
  - Substantial shelter within 1-2 km
Effectiveness of Thyroid Blocking with Time

100 mg of iodine - 130 mg of KI

Must be taken before or shortly after inhalation to be effective

Hours before inhalation

Hours after inhalation

TIME AFTER INTAKE OF $^{131}$I (hr)

100%
Total Number of Thyroid Cancers In Belarus

Among those 0-18 years old at time of Chernobyl accident
Public Monitoring and Decontamination

- Skin contamination could contribute to deterministic effects - on-site
- Public should be monitored
- Should not delay evacuation
- Screening or monitoring a sample is only practical method
- Instruct people to shower and change clothes as soon as possible
Dose Projection Models

- Do not rely on them

Tomsk Accident (due to chemical explosion)
Dose rate [$\mu$Gy/h]
Long Duration Release

- Expect all directions to be affected
Protective Action Strategy
To Reduce Public Risk for Reactor Accidents

- For large reactor (>100 MW(th) - before or shortly after release – upon detection of conditions leading to core melt
  - Evacuation or substantial sheltering area where deaths are possible
  - Take thyroid blocking where severe thyroid deterministic effects are possible
Protective Action Strategy (1)
To Reduce Public Risk for Reactor Accidents

- For reactors 2-100 MW(th) for core damage or significant release
  - Prompt shelter and monitoring near by to locate and evacuate areas where this can result in averting the GIL (50 mSv) in a week
  - Monitor and decontaminate evacuees
  - Restrict consumption of locally grown food
  - Monitoring to locate where food restrictions and relocation is warranted
Implementing Strategy

- To implement our strategy we need two things
  - Method to promptly implement protective actions and deploy monitoring teams before or shortly after release – this will be called a classification system
  - Distance to which we prepare to take protective actions this will be called are emergency zones
Emergency Classification System

• Basis for fast coordinated national and regional action
  ▪ Activation and protective action before release
  ▪ Notification of nearby countries if potential release

• Based on Emergency Action Levels – EALs
  ▪ Observable
  ▪ Risk of severe fuel damage
    ❖ Critical safety system (fuel temp > 700 C)
    ❖ Barriers damage indication (> 100 Gy/h in reactor hall)
  ▪ Environmental monitoring (> 0.01 Sv/h off-site)
IAEA Recommended Classification System

- **General Emergency (>%2 MW(th))*
  - Core damage or high off-site doses
    - Implement urgent actions off-site
    - Protect on-site personnel
    - Conduct monitoring and adjust actions
- **Site area emergency (>2 MW (th))**
  - One more failure get General Emergency
    - Prepare to take off-site actions
    - Protect on-site personnel
    - Conduct monitoring and adjust actions

* If operations allow buildup of significant amounts of I-131
IAEA Recommended Classification System

- **Facility emergency**
  - **Only on-site risk - no off-site risk**
    - Protect on-site personnel
    - Conduct monitoring and adjust actions

- **Alert**
  - **Decrease in safety**
    - Increased preparedness and assistance for on-site personnel
Establish Emergency Zones

- For effective planning and response establish emergency zones during the planning process

- Boundaries should be roads, or other features that allow easy identification

- Must not stop at national boundaries
Two Emergency Zones

- **Precautionary action zone (PAZ)**
  - Urgent protective action taken before or shortly after release within this radius should significantly reduce risk of early deaths for most postulated severe emergencies
  - Provisions to implement urgent actions before or shortly after release - based on class to reduce risk of severe deterministic effects

- **Urgent protective action planning zone (UAZ)**
  - Beyond this radius, for most postulated severe emergencies, total effective dose would not exceed urgent protective action GILs for evacuation (total effective $E(t) > 30$-50 mSv)
  - Provisions to shelter, promptly monitor and evacuate based on results
Great Uncertainty

- For example for worst postulated accident
  - Source term (release) - factor 10 to >100
  - Atmosphere transport - factor 5 to >10
  - Dose - factor 2 to >10
  - Health effects of the dose 2 to ?
How Big Are Zones?

- Due to great uncertainties - IAEA provided very general guidance based on informed judgment
- Actual size based on local conditions

<table>
<thead>
<tr>
<th>Reactors</th>
<th>PAZ</th>
<th>UPZ</th>
<th>Food restrictions radius</th>
</tr>
</thead>
<tbody>
<tr>
<td>&gt;100 MW (th)</td>
<td>0.5 – 5 km</td>
<td>5 – 25 km</td>
<td>100 – 1000 km</td>
</tr>
<tr>
<td>2 – 100 MW (th)</td>
<td>None *</td>
<td>0.5 – 5 km</td>
<td>10 – 50 km</td>
</tr>
<tr>
<td>&lt; 2 MW (th)</td>
<td>None *</td>
<td>None</td>
<td>None</td>
</tr>
</tbody>
</table>

* On-site
Example Zones for 5 MW reactor

- On-site (A, B)
- UPZ
- Air tight door
- 0.5 km

Symbols:
- F
- G
- E
- Road
- C
- H
- I
- D
- B
- A

IV3_2 Exposure Pathways and Protective Actions
## Protective Actions by Emergency Class

<table>
<thead>
<tr>
<th>Protective Action</th>
<th>Site Area Emergency</th>
<th>General Emergency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Evacuate or shelter non-essential personnel on-site</td>
<td>yes</td>
<td>yes</td>
</tr>
<tr>
<td>Provide responders with radiation protection</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Prepare the public</td>
<td>yes</td>
<td></td>
</tr>
<tr>
<td>Evacuate or shelter PAZ</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Take thyroid blocking in PAZ and UAZ</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Monitor UAZ and take action where CILS are exceeded</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Restrict fresh food and milk</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Notify nearby countries</td>
<td></td>
<td>yes</td>
</tr>
<tr>
<td>Record names of exposed for follow up</td>
<td></td>
<td>yes</td>
</tr>
</tbody>
</table>
After Start of Release

- Revise protective actions based on environmental measurements
  - Generic Intervention Levels (GIL) & Generic Action Levels (GAL)
  - Criteria for
    - Urgent actions
    - Long-term actions
    - Food restrictions
- For dose that can be prevented by action
- Intended to do more good than harm
- Taking actions at much lower levels could do more harm than good
BSS GIls and GALs

- Can not be used directly during accident
- Not directly readable on instrument
- Should develop values to be used during emergency – based on measurable quantities - default operational intervention levels (OIL)
  - OILs readable on instruments used
  - OILs used during accident to make decisions
  - Need methods to revise during accident
- IAEA has developed suggested
  - Default OILs
  - Method to revise OILs
Default gamma dose rate OILs
For reactor accident – from TECDOC- 955

- 1.0 mSv/h (100 mR/h) - Evacuate
  (10000 x background)

- 0.2 mSv/h (20 mR/h) - Relocate

- 0.1 mSv/h (10 mR/h) - Thyroid blocking

- 1.0 µSv/h (100 µR/h) - Restrict local food

- 0.1 µSv/h (10 µR/h) - Typical Background
Use of OILs

- Use default Oils

  Determine where OILs exceeded - Take protective actions

  Determine accident specific information

  Recalculate OILs

  Adopt revise OILs

  Major differences?

  NO

  Yes
Protective Action Strategy for Reactor Accident

- For PAZ (early deaths are possible with a few hours)
  - Implement sub. shelter or evacuate to reduce this risk - when dangerous condition detected.
- For UPZ (urgent protective actions may be warranted in accordance with the BSS GIL)
  - Shelter and conduct prompt monitoring to determine if evacuation is warranted.
- Give thyroid blocking near the facility
- Restrict locally predicted food consumption
Example Protective Actions upon detection of Site Area or General Emergency (e.g., > 0.1 Gy/h in Building A) for the 5 MW Reactor

Actions:
• Evac On-site A, B
• Protect responders
• Shelter C monitor first
• Block road at F, G, H, I
• Monitor UPZ boundary and D, E, F – if > 1 mSv/h evacuate – expand controlled zone
First Hour of Severe Accident

- Event detected by control room (0:00)
- Classified and emergency is declared (+ 5 min)
- Off-site officials notified - Building Evacuated (+ 15 min)
- Off-site officials decide on action (< 30 min)
- Sirens sound and public turns on radio (< 45 min)
- Radio message advises public to take action (< 45 min)
- Public starts to take action (< 60 min)
- Near-by countries notified (+ 60 min)
- Extensive environmental monitoring begun
- Additional actions taken at levels consistent with International guidance
Psychological Considerations

- Evacuations are common - people do not panic!
- Travel during evacuations is safer than normal travel
- Some people will act on their own and not follow instructions
- There will be better compliance with advice if trust is maintained by
  - ongoing information programme
  - clear and simple advice during emergency
  - consistent advice and assessment (one official information point)
  - using international guidance
Psychological Health Effects

- Expected after nuclear accident

- At Chernobyl some actions did more harm than good

- Psychological effects must be considered in making decisions

- Do not take protective actions for political reasons
Treatment of Overexposures and Contamination

- Medical personnel may not be willing to treat if not trained
- Treatment of severe overexposures requires consultation with experts
Summary

- Before any release the only information on which to base protective actions is the plant status (accident class)

- Close to the site actions may need to be taken very quickly (within 1 to 2 hours)
Where to Get More Information

- IAEA BSS for basic requirements
- TECDOC-953 (undergoing revision) for general guidance
- TECDOC-955 for technical procedures for reactors
- TECDOC-1092 for technical procedures for monitoring