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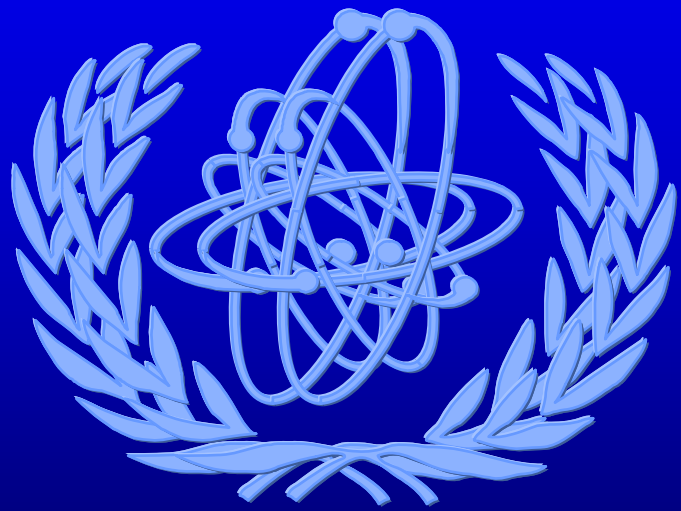
Radiation Emergencies – Common Features

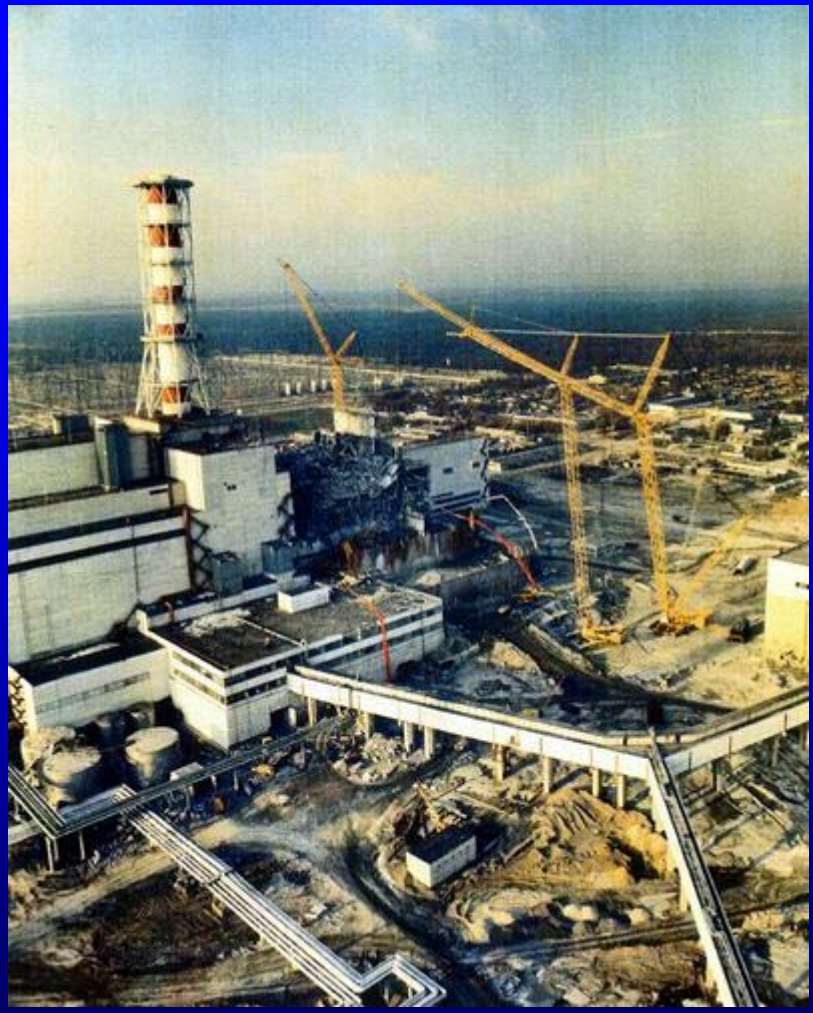


Exposure Pathways and Protective Actions

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

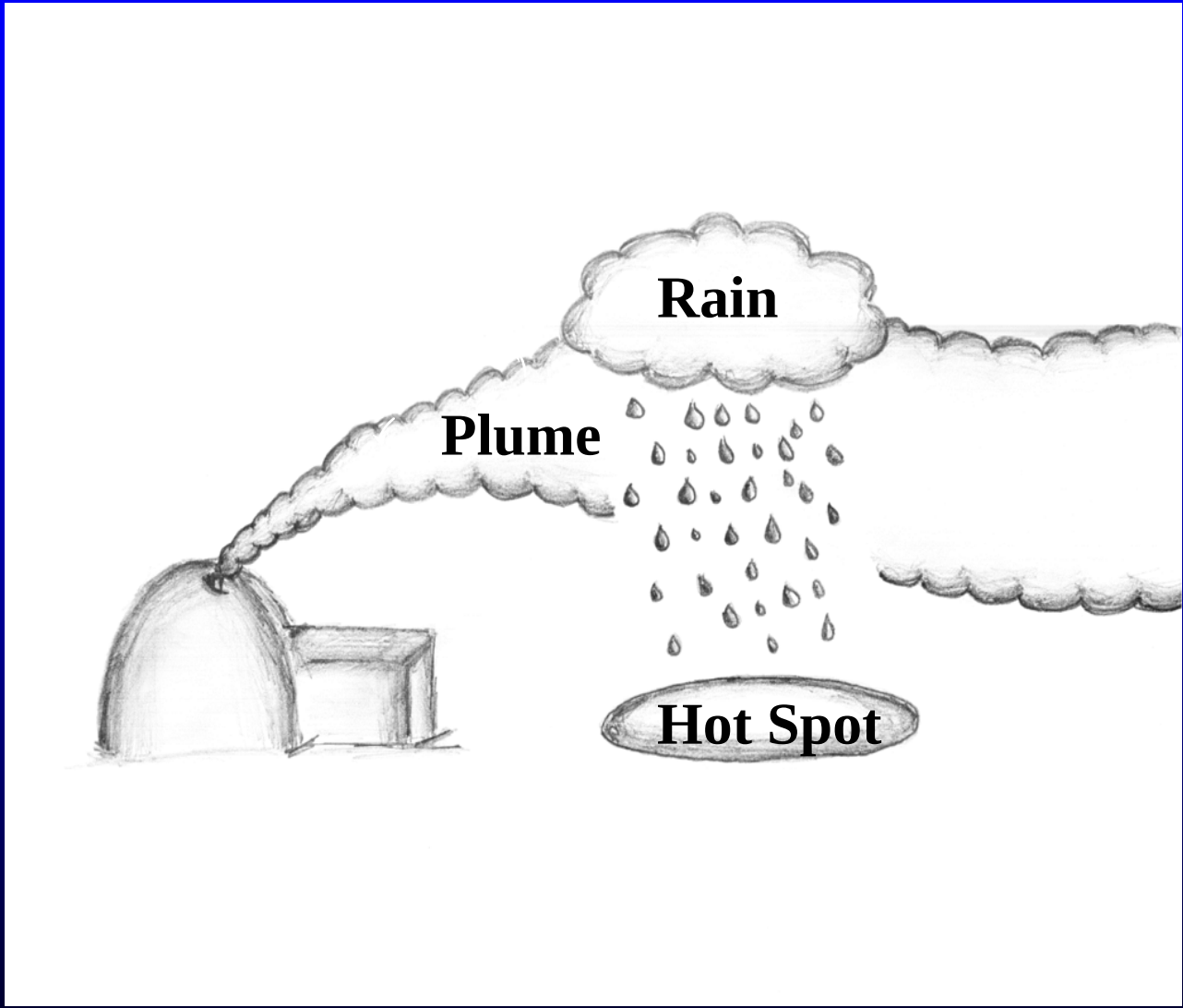
Objectives of Emergency Response

- 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 according to international guidance

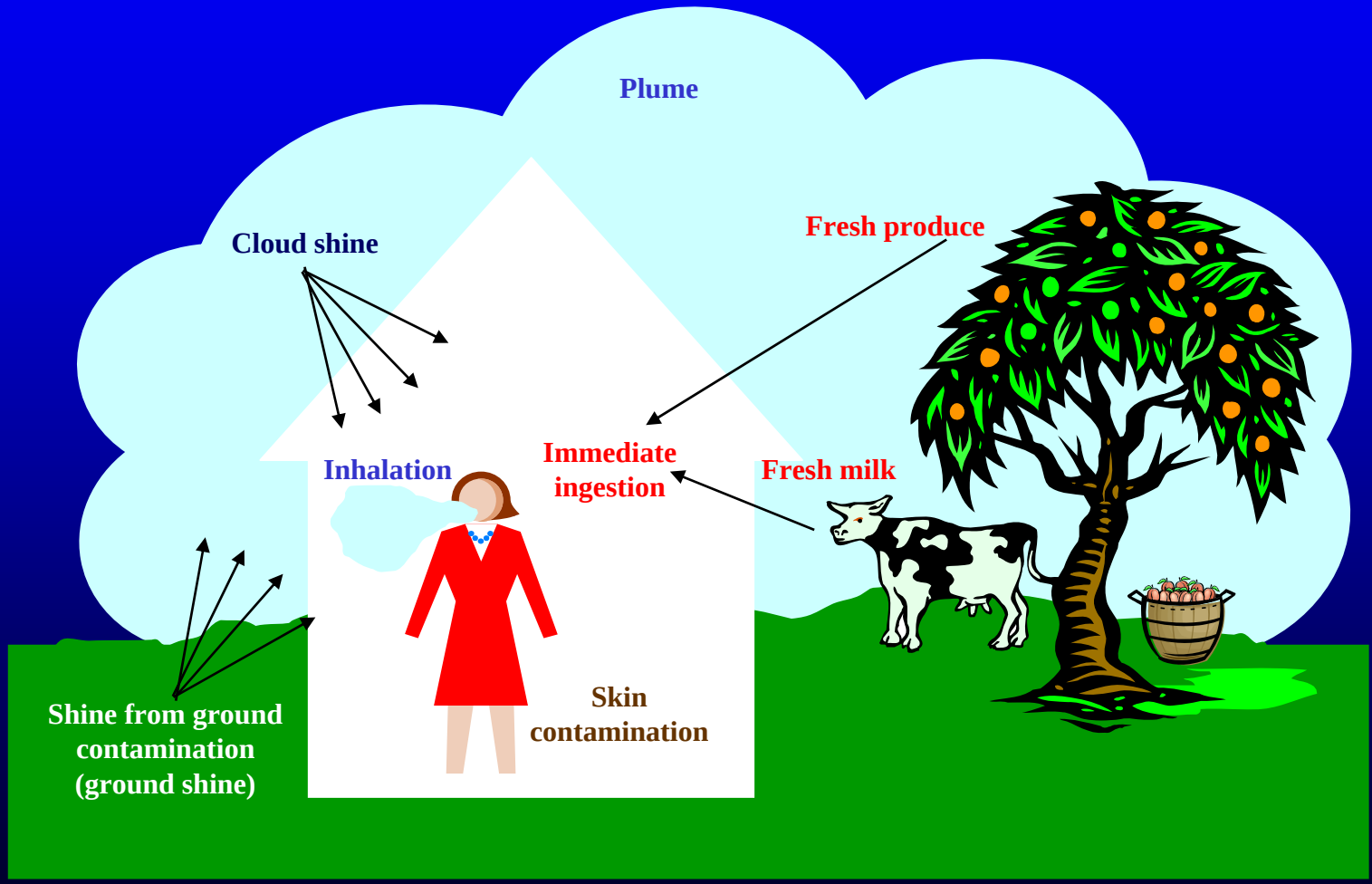
International Guidance (BSS)

- Take all action to keep dose below threshold for serious acute effects (2 day exposure)
  - Bone morrow - 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



Human Exposure Pathways

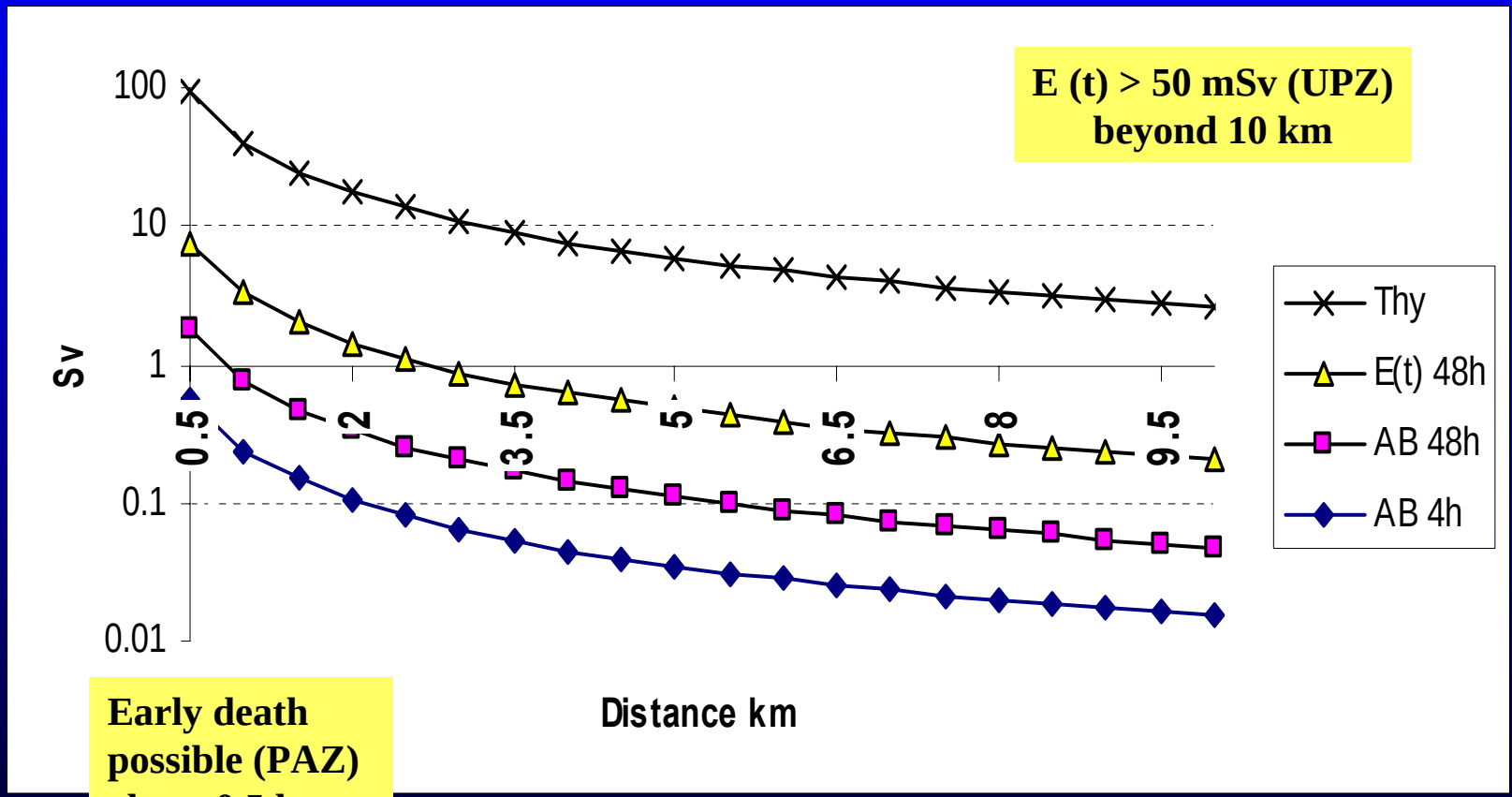


Reactor Emergencies

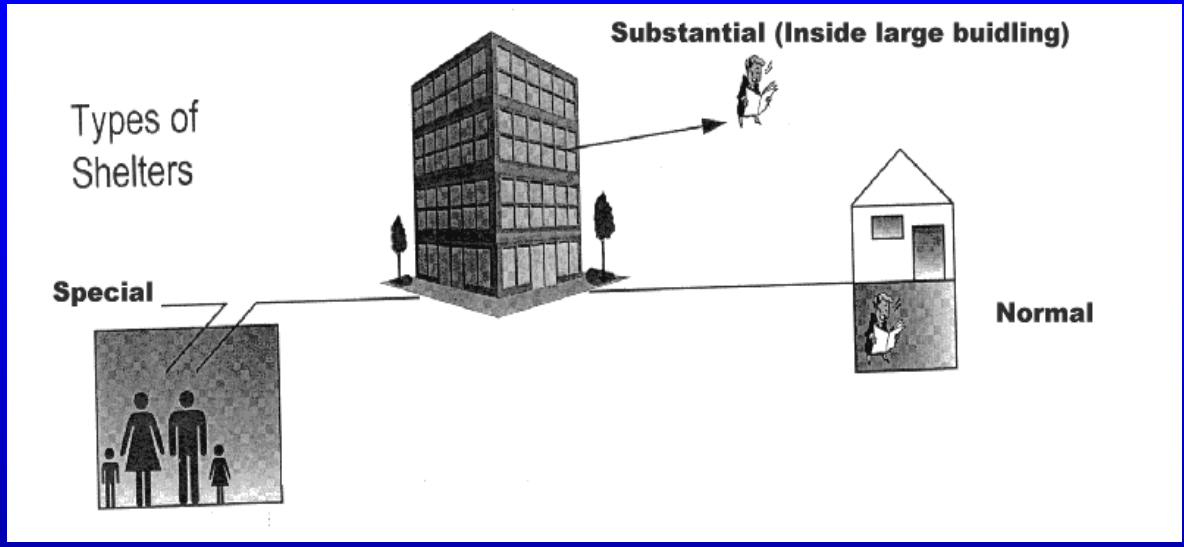
- Releases resulting in off-site health effects possible for
  - Severe damage to 100 MW(th) or larger core and fast – direct release
  - Build up of I-131 - continuous operation
- Release warranting evacuation (exceed GILs) or food restriction (exceed GALs)
  - Severe damage to > 2 MW(th) core
- Below 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**

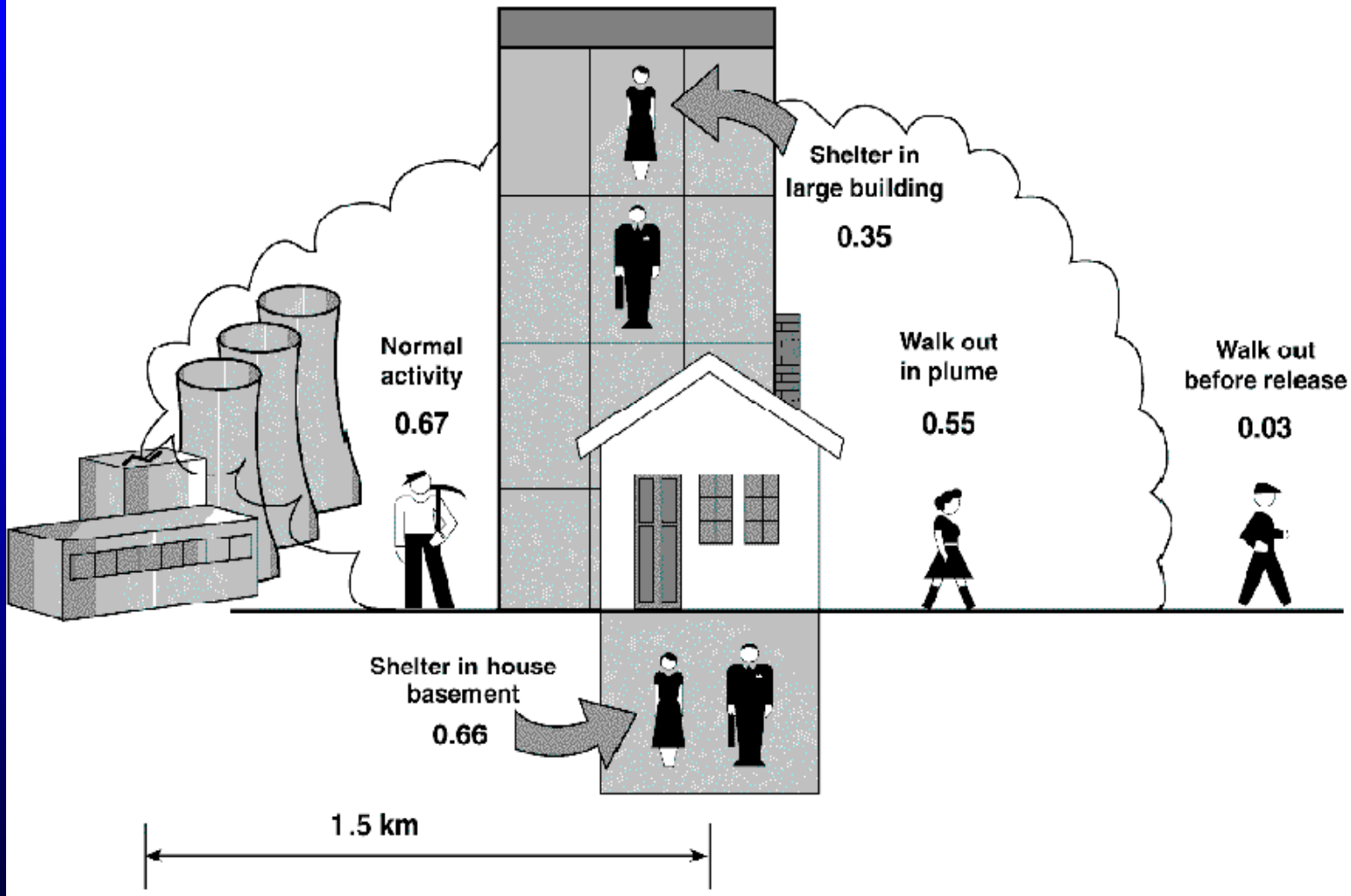


Types of Shelters and Effectiveness



	Normal	Substantial	Special
Cloud Shine	0.4 - 0.9	0.1 - 0.2	> 0.001
Ground Shine	0.01 - 0.1	0.005 - 0.01	> 0.0001
Inhalation	0.3 - 0.5	0.3 - 0.5	> 0.001

PROBABILITY OF EXCEEDING EARLY DEATH THRESHOLD FOR SEVERE ACCIDENT

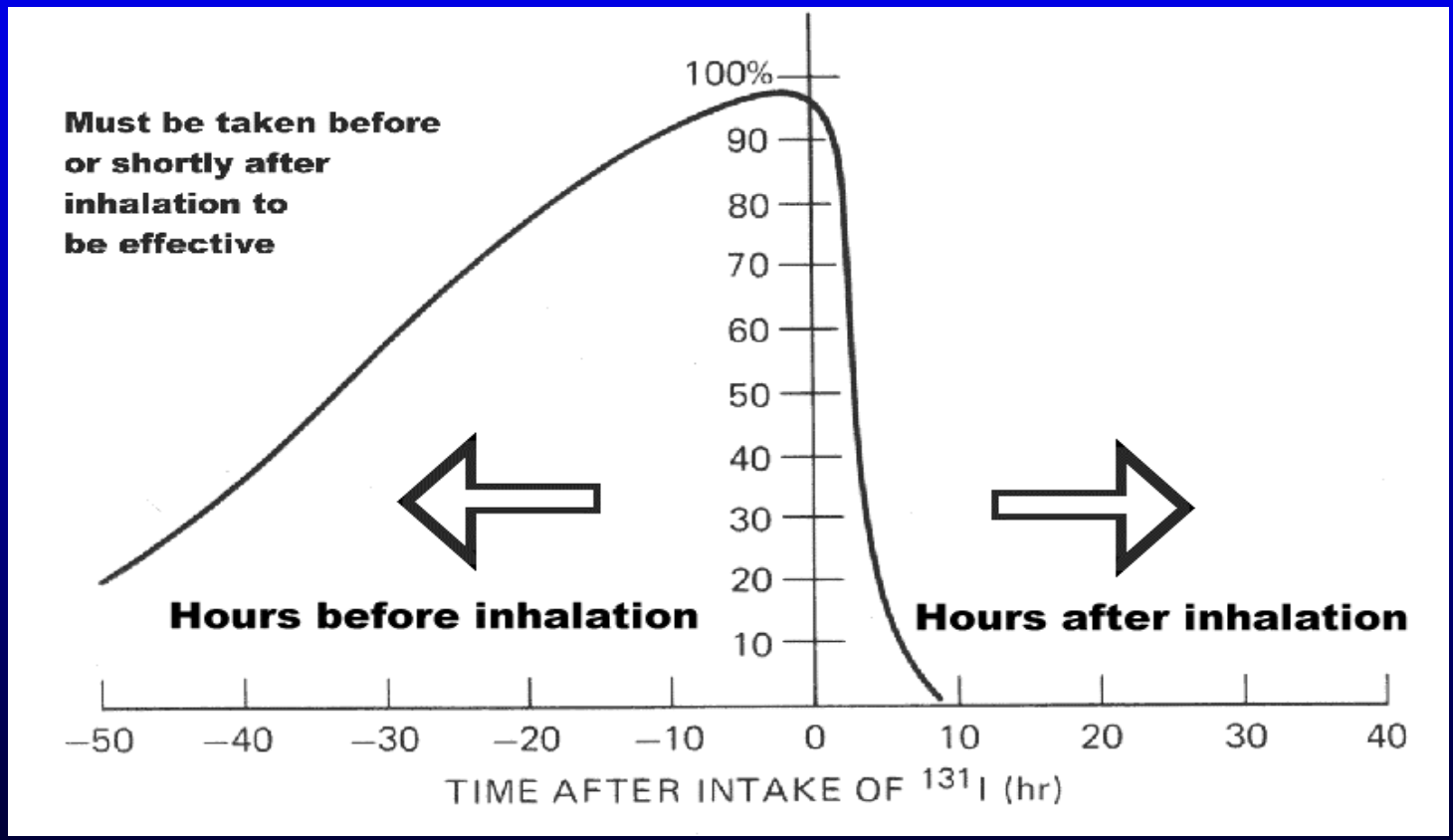


Shelter vs Evaluation for a Reactor Accident

- **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**

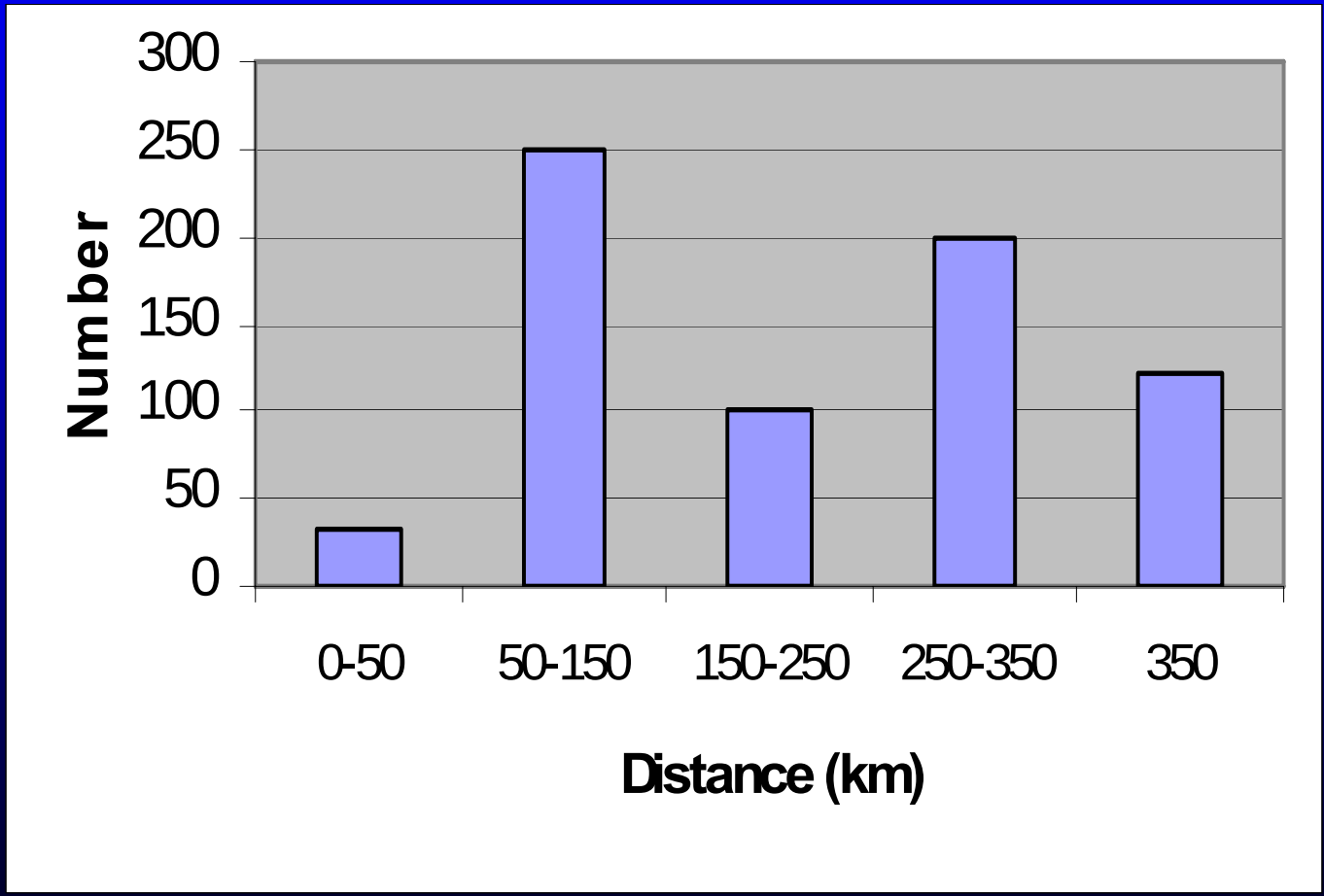
Effectiveness of Thyroid Blocking with Time

100 mg of Iodine - 130 mg of KI



Total Number of Thyroid Cancers In Belarus

Among those 0-18 years old at time of Chernobyl accident



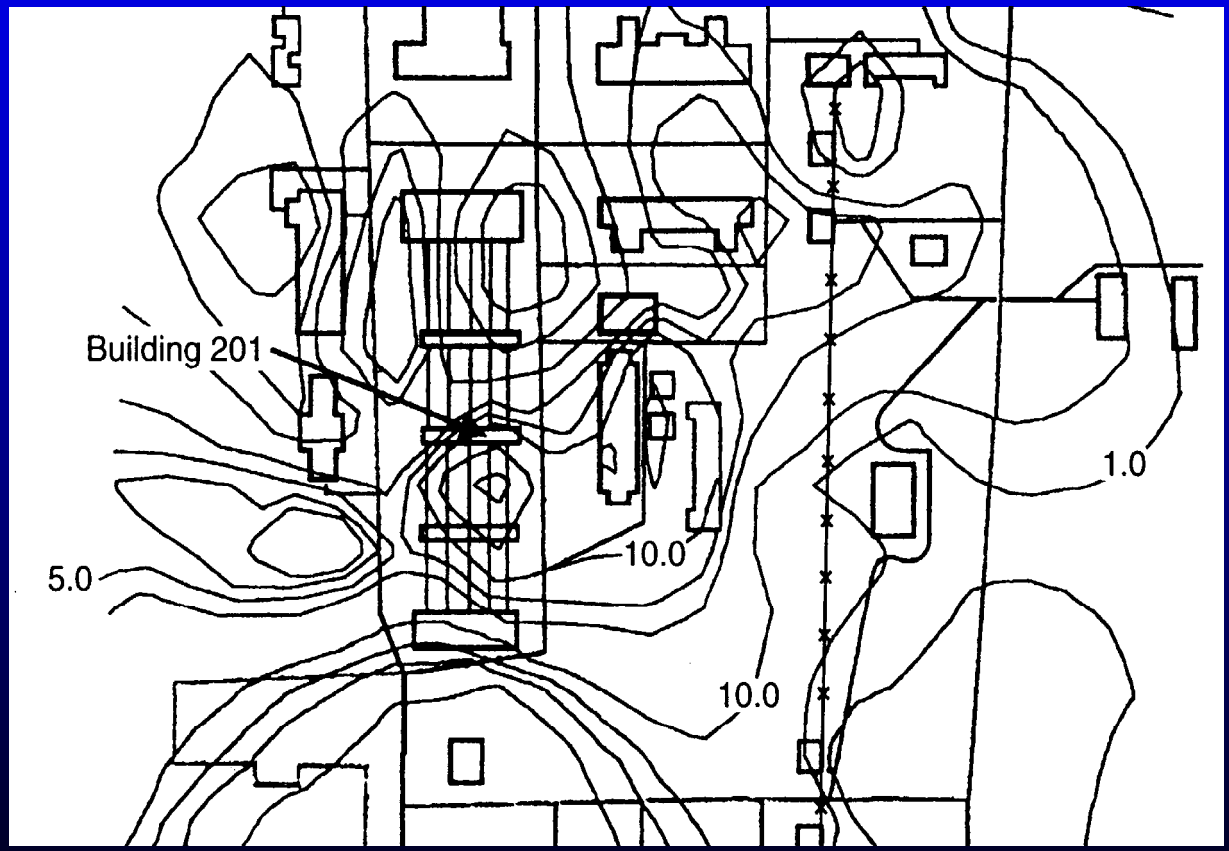
Public Monitoring and Decontamination

- 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

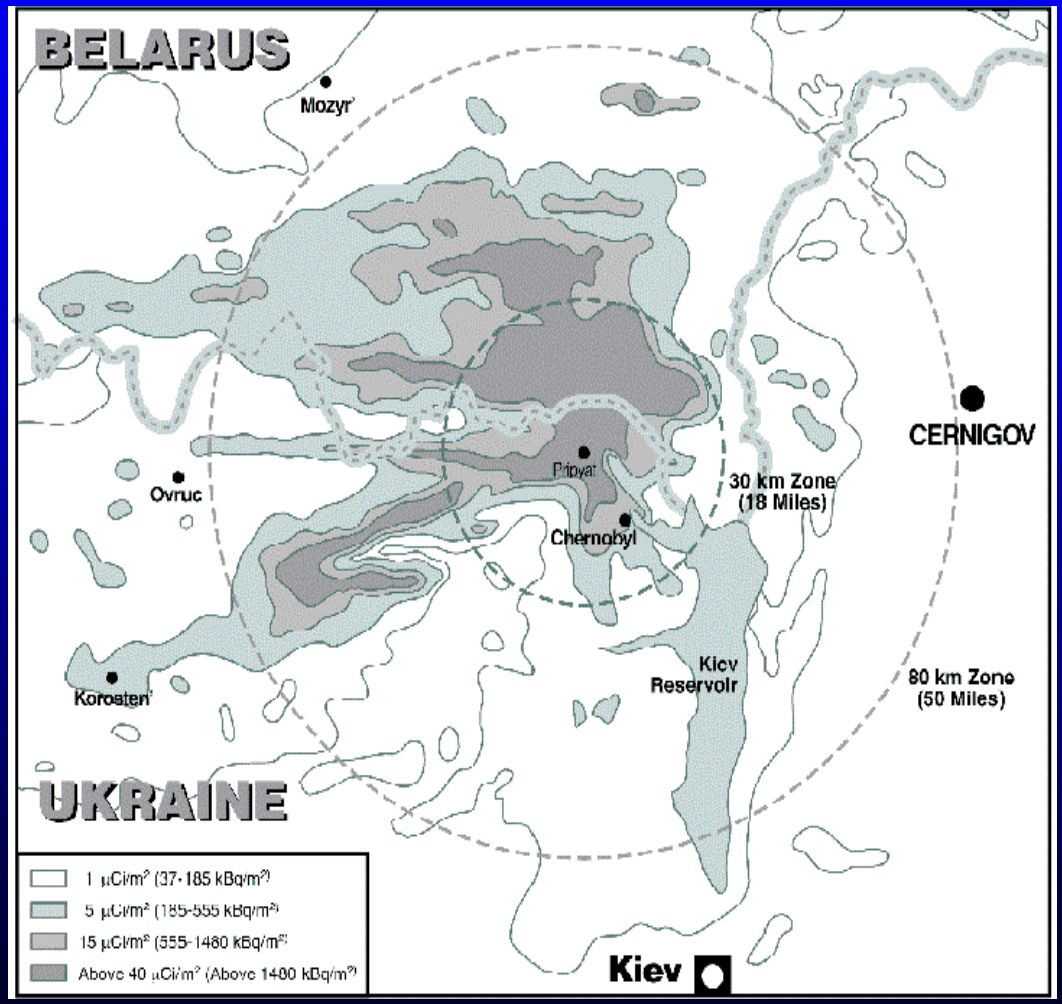
- Do not rely on them

Tomsk Accident (due to chemical explosion)
Dose rate [μGy/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 ?

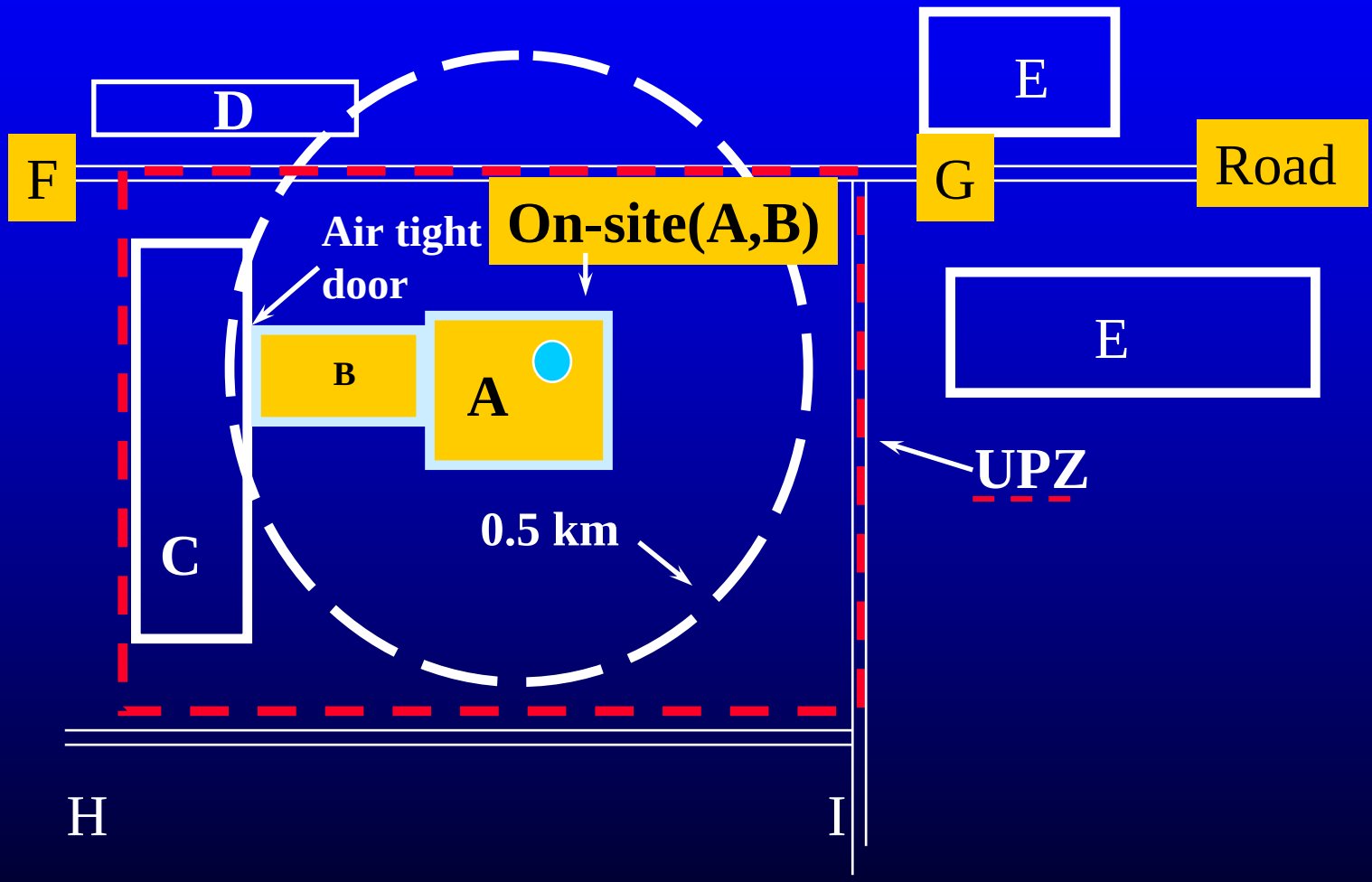
How Big Are Zones?

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

Reactors	PAZ	UPZ	Food restrictions radius
>100 MW (th)	0.5 – 5 km	5 – 25 km	100 – 1000 km
2 - 100 MW (th)	None *	0.5 – 5 km	10 – 50 km
< 2 MW (th)	None *	None	None

* On-site

Example Zones for 5 MW reactor



Protective Actions by Emergency Class

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

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

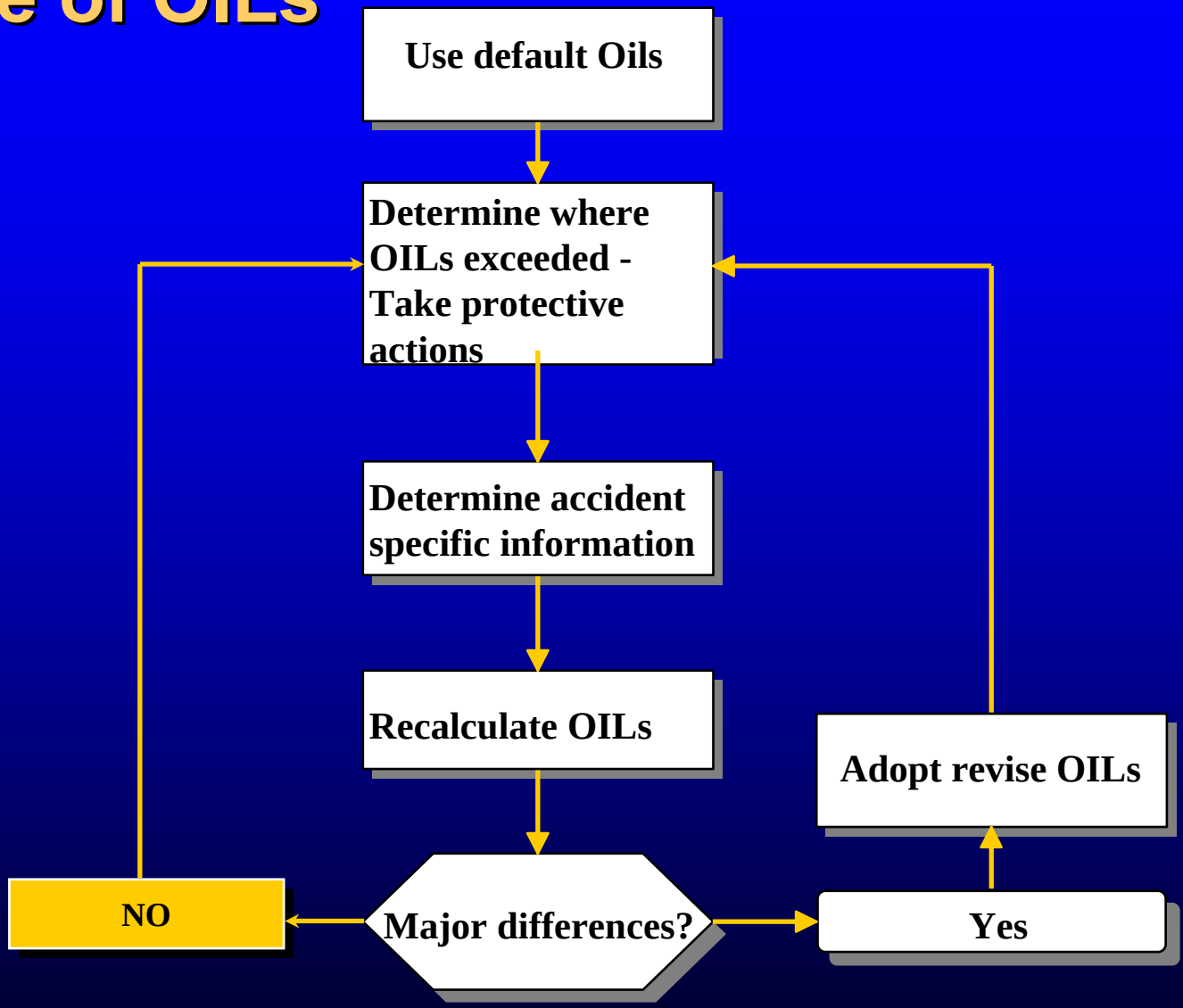
- Can not be used directly during accident
- Not directly readable on instrument
- Should develop values to be used during emergency – based on measurable quantities - default operational intervention levels (OIL)
  - OILs readable on instruments used
  - OILs used during accident to make decisions
  - 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 (100µR/h) - Restrict local food

0.1 µSv/h (10µR/h) - Typical Background

Use of OILs

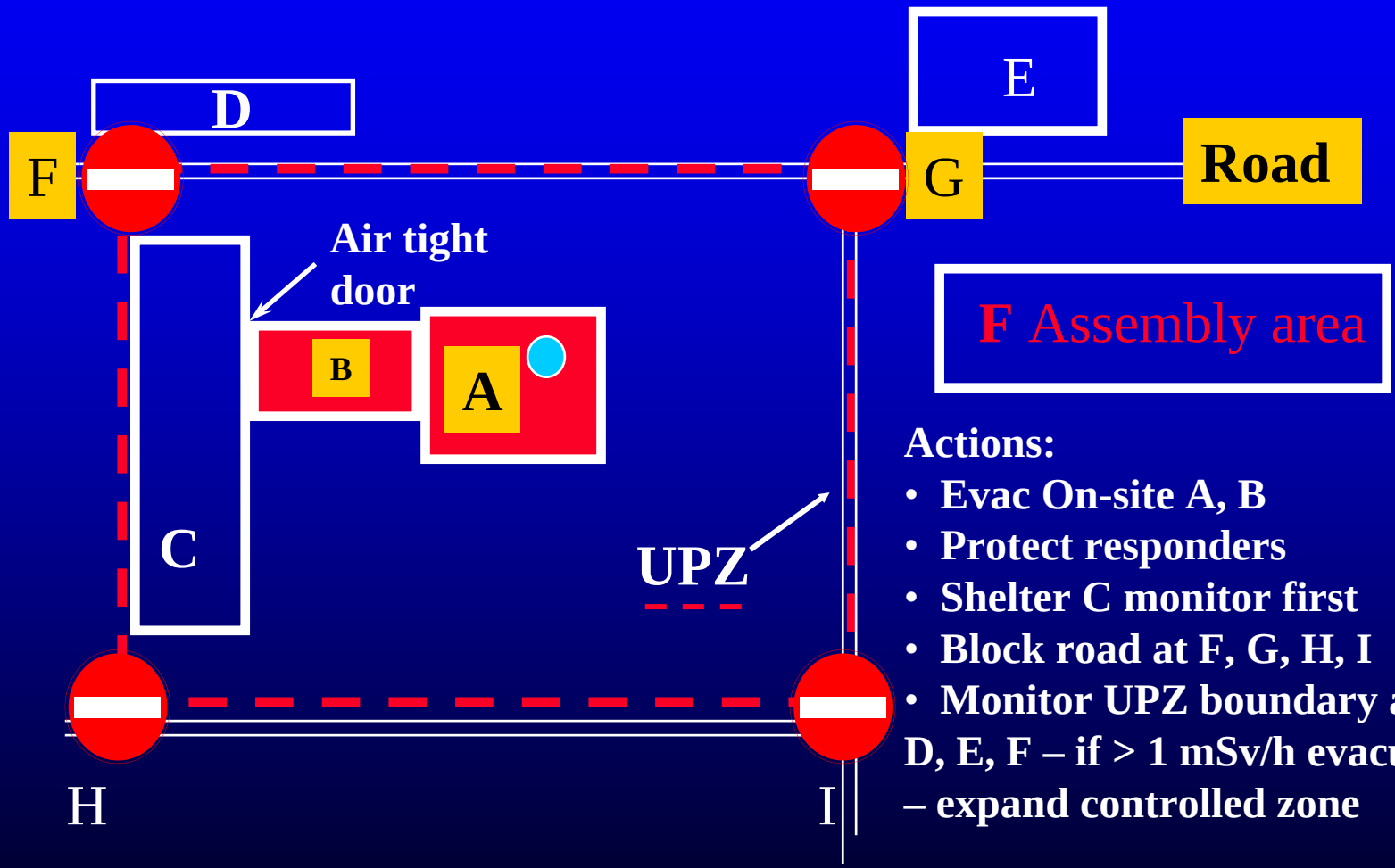

Use default Oils
Determine where OILs exceeded - Take protective actions
Determine accident specific information
Recalculate OILs
Major differences?
NO
Yes
Adopt revise OILs

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