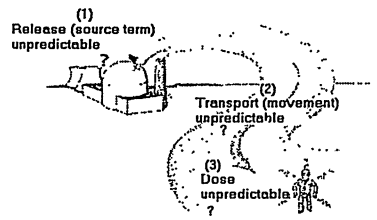
RELEASES FROM THE CORE AND IN THE ENVIRONMENT

MODULE II

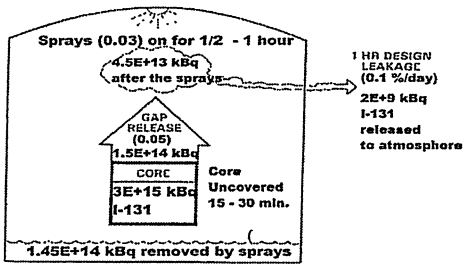
DOSE PROJECTION TOO LATE AND TOO UNCERTAIN AS BASIS FOR PROTECTIVE ACTIONS



ESTIMATION OF SOURCE TERM

- Estimate of release
  - composition (isotopic mixture)
  - rate (Bq/s)
  - time (early - late)
  - length of release
  - elevation
- Determined by core damage and release route
- Very large uncertainties

SOURCE TERM ESTIMATION



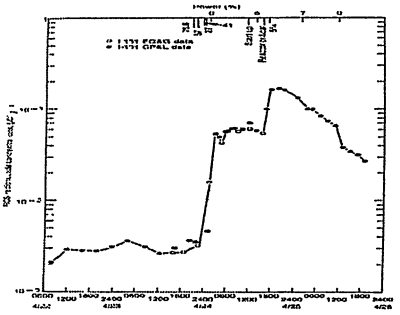
CORE INVENTORY

- Assume standard inventory at end of cycle
- Adjust assumptions for power level in
  - IAEA generic procedures TECDOC-955
- Sufficiently accurate for most reactor designs

RELEASE FROM CORE

- Use simple estimates, because of great uncertainties
- Four core damage states used in IAEA generic procedures
  - Normal coolant
  - Spiked coolant
  - Gap
  - Core melt
- Best that can be made based on plant information

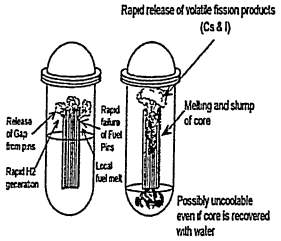
NORMAL - SPIKED COOLANT



II - 7

ASSUMED FRACTIONS RELEASED FROM THE CORE AFTER IT IS UNCOVERED

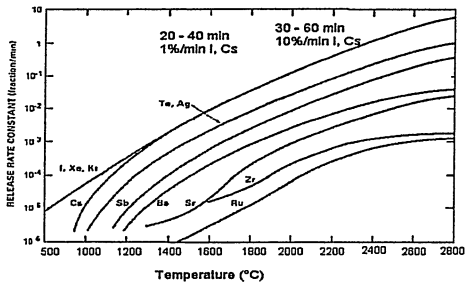
- Gap Release
  - 5 % of Iodine, Cesium and Noble Gases Inventory



- Core Melt
  - 25 - 35% of Iodine and Cesium Inventory
  - 95% of Noble Gases Inventory
  - 0.01 - 10% of others

II - 8

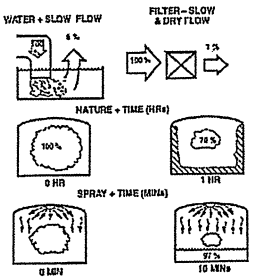
WE USE VERY SIMPLE ESTIMATES OF A VERY COMPLEX PROCESS



II - 9

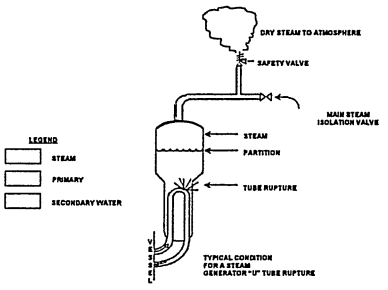
MAJOR RELEASE ROUTE REDUCTION MECHANISMS

- Noble gases (Kr, Xe) are not reduced
- Major removal mechanisms for non-noble gases are shown
- You must identify release routes and reduction mechanism for your site



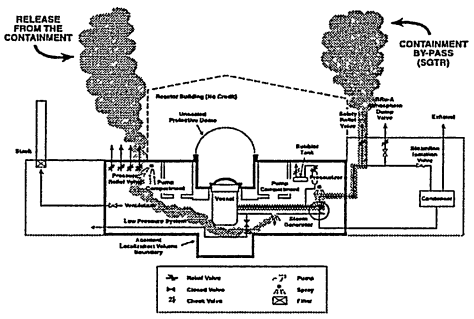
II - 10

STEAM GENERATOR PARTITIONING



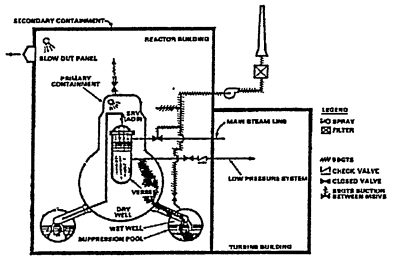
II - 11

WWER-440 V230 SIMPLIFIED RELEASE PATHWAYS



II - 12

BWR AND WWER-213 HAVE POOLS



II - 13

IAEA GENERIC RELEASE ROUTES

- Release from containment
- Containment by-pass under dry conditions
- Containment by-pass under wet conditions
- Release from spent fuel pool

II - 14

RELEASE RATE IS VERY UNCERTAIN

Most major releases are:

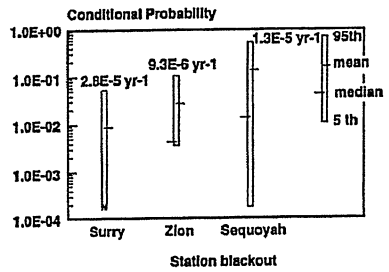
- unpredictable
- at unmonitored points

Very simple estimates of rate are used because of uncertainty of containment releases

< 0.1 %/day - Design rate
100%/day - major leak
100%/hour - total failure

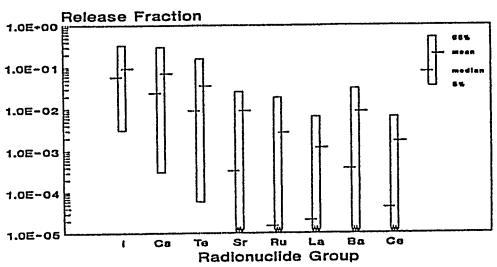
II - 15

PROBABILITY OF AN EARLY CONTAINMENT FAILURE



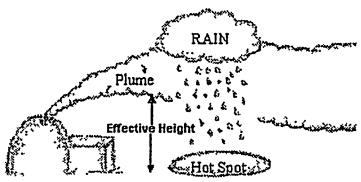
II - 16

THE ESTIMATED UNCERTAINTY FOR RELEASE FROM A CORE MELT WITH EARLY CONTAINMENT FAILURE (USA RESEARCH RESULT)



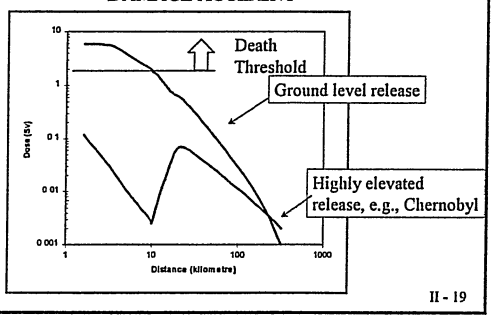
II - 17

THE RELEASE



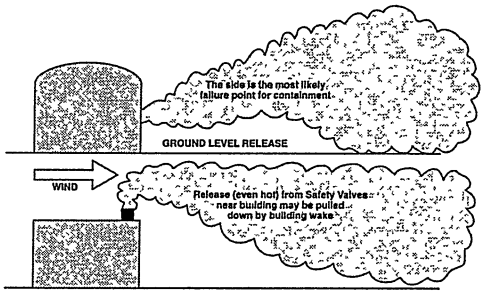
II - 18

PROJECTED BONE MARROW DOSE FOR GROUND LEVEL AND ELEVATED RELEASES - SEVERE CORE DAMAGE ACCIDENT



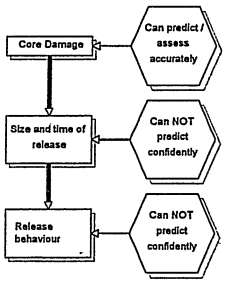
II - 19

RELEASE HEIGHT



II - 20

EARLY ACCIDENT ASSESSMENT



II - 21

THE RELEASE

- Dose rates in the plume will be variable
- Deposition will be complex
- Models cannot accurately predict for many accidents

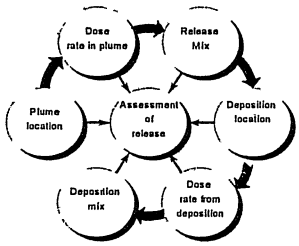
II - 22

AFTER THE START OF RELEASE

- Conduct environmental monitoring
- Used to adjust protective action

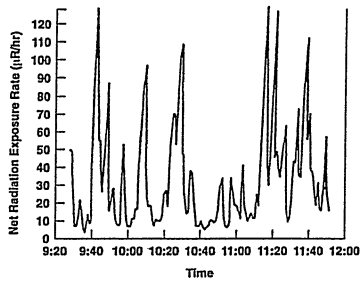
II - 23

ASSESSMENT OF THE RELEASE



II - 24

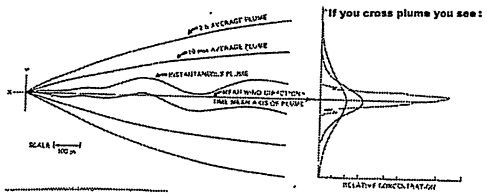
FIELD EXPOSURE RATES MEASUREMENTS
(WITH CONSTANT WIND DIRECTION)



II - 25

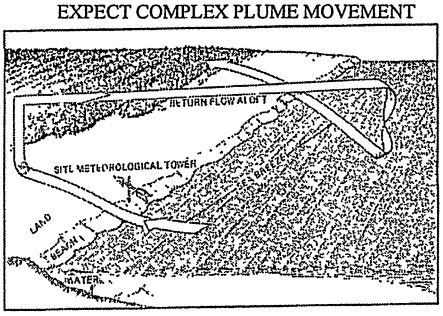
MEASUREMENTS IN PLUMES

- Plumes move even if the wind direction is steady
- Models and assessments based on averages (10 -15 min.)



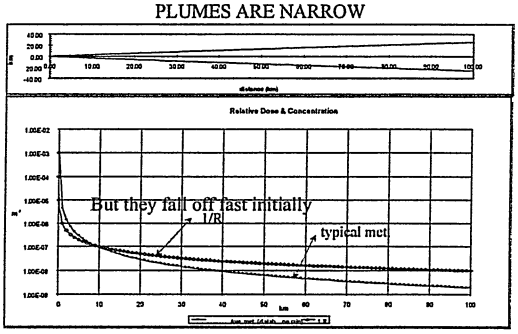
II - 26

EXPECT COMPLEX PLUME MOVEMENT



II - 27

PLUMES ARE NARROW



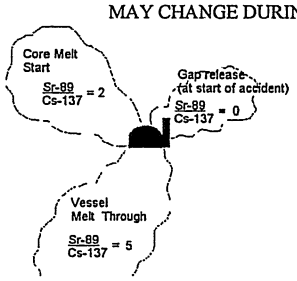
II - 28

ISOTOPIC MIXTURE OF RELEASE

- Release composed of complex fission product mix
- Mix determines inhalation and ingestion dose
- Mix difficult and time consuming to determine
- Initially defaults (estimates) used
- Later adjusted based on measurements

II - 29

ISOTOPIC MIXTURE IN PLUME MAY CHANGE DURING RELEASE

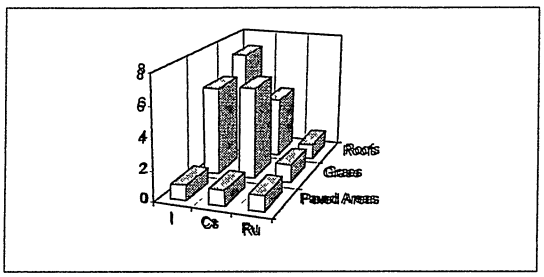


- Different by core damage state and route
- Confirm by monitoring
- Can change during release with wind direction

II - 30

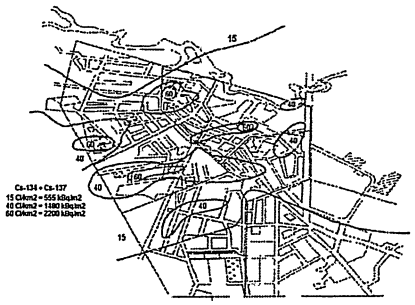
EXPECT DEPOSITION RATES TO VARY

RATES FOR VARIOUS SURFACES RELATIVE TO DEPOSITION ON PAVED AREAS AT CHERNOBYL



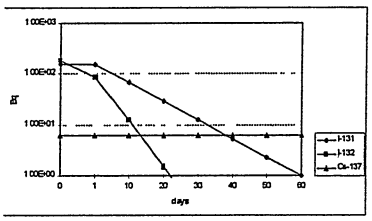
II - 31

EXPECT HOT SPOTS - VARIATION OF DEPOSITION



II - 32

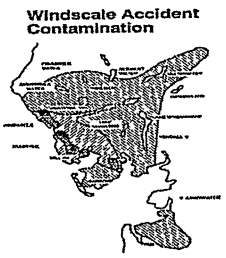
EXPECT CHANGE IN MIXTURE WITH TIME DECAY - INGROWTH

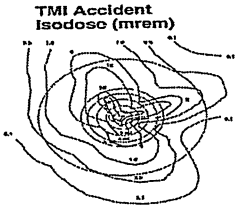


RELATIVE ACTIVITY OF I-131, I-132 AND Cs-137 AFTER REACTOR SHUTDOWN

II - 33

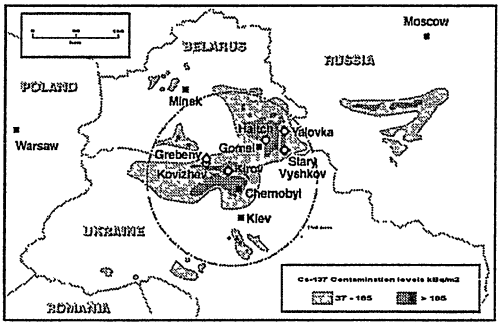
EXPECT ALL DIRECTIONS TO BE AFFECTED BY A LONG DURATION RELEASE





II - 34

DEPOSITION COULD COVER A LARGE AREA



II - 35

CONSIDERED IN DEVELOPMENT OF IAEA GENERIC PROCEDURES

- Release results in complex pattern not predictable by models
- All directions affected for long duration release
- Rain and other effects produce hot spots
- Deposition mixture differs by location, surface and time
- Must consider plant condition in initial assessment of environment data
- Only monitoring and sampling can tell

II - 36

EXPOSURE PATHWAYS AND PROTECTIVE ACTIONS

MODULE III

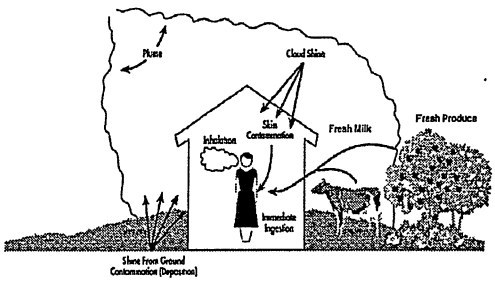
III - 1

OBJECTIVES OF EMERGENCY RESPONSE

- Mitigate the accident at its source
- Reduce the risk of serious deterministic health effects (deaths)
  - Keep acute dose below health effects threshold
- Reasonably reduce the risk of stochastic effects (cancers)
  - Do more good than harm
  - Act according to international guidance

III- 2

IMPORTANT EARLY DOSE PATHWAYS FOR REACTOR ACCIDENTS



III- 3

Pathways, Phases, and Protective Actions

PATHWAYS	PHASES	PROTECTIVE ACTIONS
Cloud Shine	URGENT	Sheltering Evacuation Control of Access
Plume Inhalation	URGENT	Sheltering Use of Potassium Iodide Evacuation Respiratory Protection Control of Access
Skin Contamination	URGENT	Sheltering Evacuation Decontamination of Persons
Short Term Ground Shine	URGENT	Evacuation Relocation Decontamination of Land and Property
Immediate Ingestion	URGENT	Food and Water Controls
Long Term Ingestion	LONG TERM	Food and Water Controls
Long Term Ground Shine and Inhalation of Resuspended Activity	LONG TERM	Relocation Decontamination of Land and Property Restricted Use

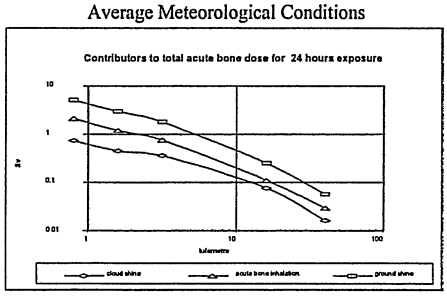
III- 4

ACUTE DOSE vs. EFFECTIVE DOSE

- Total effective dose (reflects risk of cancer)
  - External dose +
  - Internal committed dose for lifetime (50 - 70 y) after inhalation or ingestion
- "Acute" dose (reflects risk of deterministic effects)
  - External dose +
  - Internal dose for 2 days after inhalation or ingestion
- Reactor accidents Internal Dose
  - Life time effective dose = about 10 times acute bone marrow

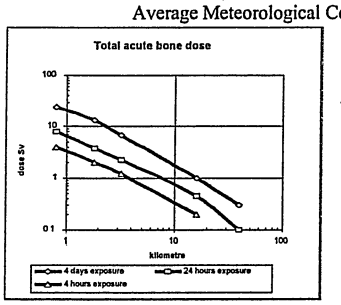
III- 5

TYPICAL ASSESSMENT
Core Melt With Early Containment Failure - No Rain, Average Meteorological Conditions



III- 6

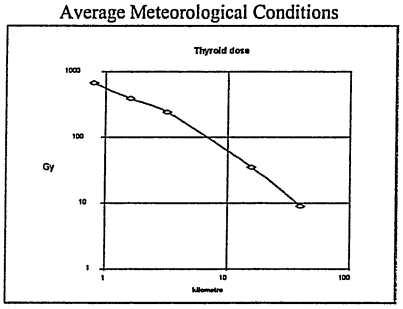
TYPICAL ASSESSMENT
Core Melt With Early Containment Failure - No Rain,
Average Meteorological Conditions



- Early death threshold (1 Sv bone marrow) exceeded out to
  - –5 km in 4 hours
  - –10 km in 24 hours
  - –20 km in 4 days

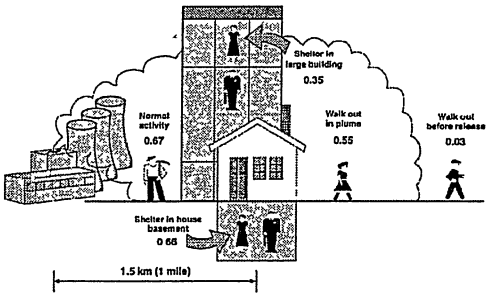
III- 7

TYPICAL ASSESSMENT
Core Melt With Early Containment Failure - No Rain,
Average Meteorological Conditions



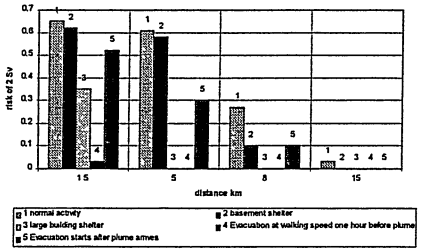
III- 8

PROBABILITY OF EXCEEDING EARLY
DEATH THRESHOLD FOR SEVERE ACCIDENT



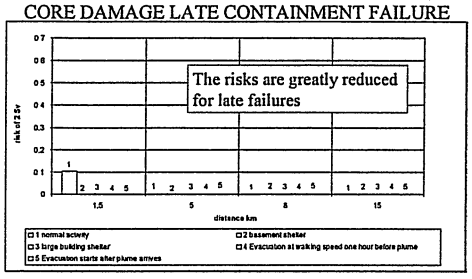
III- 9

PROBABILITY OF EXCEEDING 2 SV ACUTE BONE
DOSE (ABOVE EARLY DEATH THRESHOLD)
CORE DAMAGE EARLY CONTAINMENT FAILURE



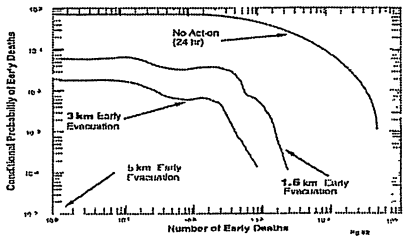
III- 10

PROBABILITY OF EXCEEDING 2 SV ACUTE BONE
DOSE (ABOVE EARLY DEATH THRESHOLD)
CORE DAMAGE LATE CONTAINMENT FAILURE



III- 11

PROBABILITIES OF FATALITIES ASSUMING
LARGEST REACTOR ACCIDENT



Evacuation at time of the release to 5 km followed by evacuation of hot spots in 4 - 6 hours *PREVENTS* early deaths

III- 12

FOR THE TYPICAL CORE MELT ACCIDENT WITH EARLY CONTAINMENT FAILURE

- Acute inhalation dose and ground shine
  - major contributors to deaths within 2 km
- Ground shine most important > 2 km
- Close in-take action quickly to avert dose from plume
- Monitor further, and evacuate hot spots

III- 13

RISK PERSPECTIVE

I NORMAL OPERATIONS:

$\frac{1}{1{,}000{,}000\ YRS}$ (EARLY FATALITY RISK)

II PROBABILITY OF CORE MELT:

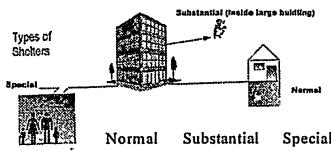
$\frac{1}{10{,}000\ YRS}$ to $\frac{1}{100{,}000\ YRS}$

III LARGE RELEASE PROBABILITY GIVEN CORE MELT:

$\frac{0.5}{100}$ to $\frac{1}{2}$

III- 14

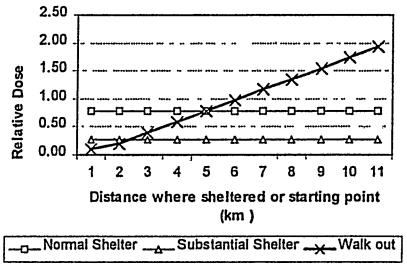
TYPES OF SHELTERS AND EFFECTIVENESS



	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

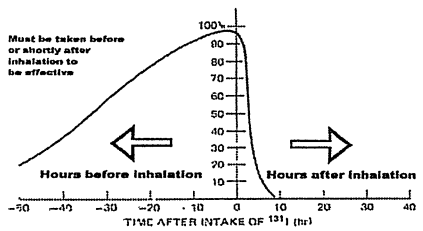
III- 15

Effectiveness of sheltering and evacuation in plume



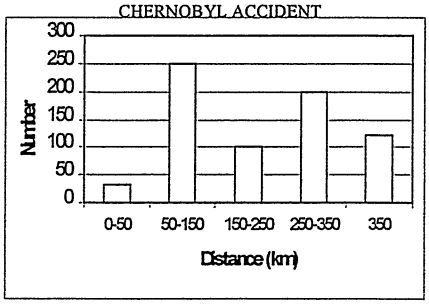
III- 16

EFFECTIVENESS OF THYROID BLOCKING WITH TIME
100 mg OF IODINE - 130 mg OF KI



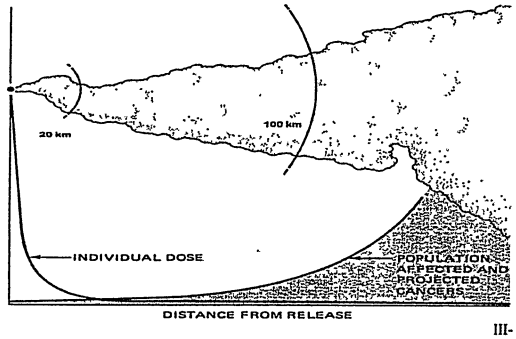
III- 17

TOTAL NUMBER OF THYROID CANCERS IN BELARUS AMONG THOSE 0-18 YEARS OLD AT THE TIME OF CHERNOBYL ACCIDENT



III- 18

MOST CANCERS WILL BE MORE THAN 100 KM FOR SITE



III- 19

PUBLIC MONITORING AND DECONTAMINATION

- Skin contamination could contribute to deterministic effects
- 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

III- 20

PROTECTIVE ACTION STRATEGY TO REDUCE PUBLIC RISK FOR CORE DAMAGE ACCIDENTS

- Before or shortly after release - based on plant conditions
  - Evacuation or substantial sheltering within 3 - 5 km
  - Take thyroid blocking near the plant
- After a release
  - Prompt monitoring to locate areas requiring further protective actions.
  - Restrict consumption of locally grown food out to 300 km
  - Monitoring to locate where food restrictions and relocation is warranted

III- 21

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:
  - an ongoing information programme
  - clear and simple advice during the accident.
  - consistent advice and assessment (one offical information point)
  - using international guidance

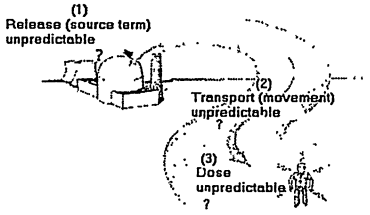
III- 22

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

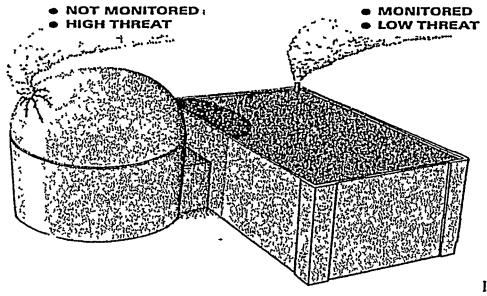
III- 23

DOSE PROJECTION TOO LATE AND TOO UNCERTAIN AS BASIS FOR PROTECTIVE ACTIONS



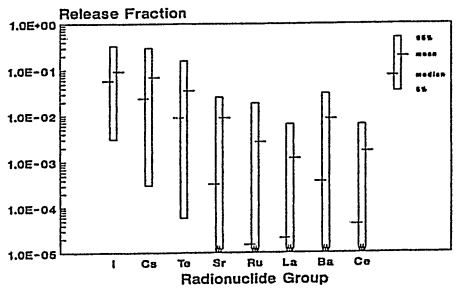
III- 24

IF THERE IS A MAJOR RELEASE IT MOST LIKELY WILL NOT BE MONITORED



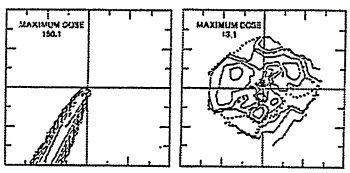
III- 25

ESTIMATED FISSION PRODUCT RELEASE FRACTIONS - CORE MELT AND EARLY CONTAINMENT



III- 26

DOSE PROJECTION MODEL
Models may not accurately project plume movement

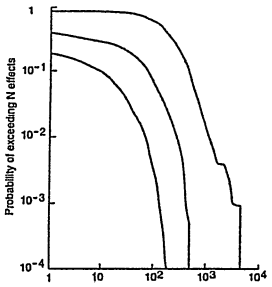


PROJECTION ACTUAL

BE CAREFUL!

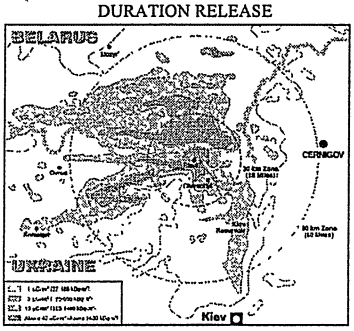
III- 27

EXAMPLE FOR THE RANGE OF UNCERTAINTY AROUND THE BEST ESTIMATE FOR THE NUMBER OF EARLY DEATHS



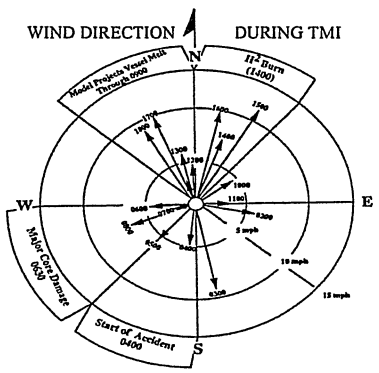
III- 28

EXPECT ALL DIRECTIONS TO BE AFFECTED BY A LONG DURATION RELEASE



III- 29

WIND DIRECTION DURING TMI



III- 30

DEVELOP AN EMERGENCY CLASSIFICATION SYSTEM

- Basis for fast co-ordinated national and regional action
  - Activation and notification
  - Protective action before a release
  - Notification of nearby countries if potential release
- Based on
  - Risk of core damage
    - Critical safety system
    - Barriers (core damage indication)
  - Environmental monitoring

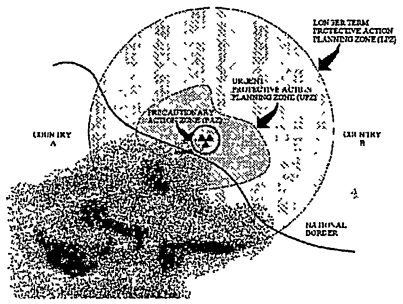
III- 31

IAEA RECOMMENDED EMERGENCY CLASSIFICATION SYSTEM

Class	Description	On-Site Action	Off-Site Action
Alert	Decreased safety Unknown Conditions	Partial Activation of Response Assist Control Room	Increase Readiness
Site Area Emergency	Major Decrease in Safety One more Failure Results in Core damage High Dose On-Site	Full On-Site Response Evacuate or shelter non-essential personnel On-Site Monitor	Fully Activated Response
General Emergency	Substantial Risk of Major Release Actual or Projected Core Damage High Dose Off-Site	Same As Site Area + Recommended Protective Action to Off site Officials	Same Site Area + Implement Urgent Protective Actions near the site Notify IAEA and near by countries

III- 32

PROTECTIVE ACTION ZONES



III- 33

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	yes	
publicate or shelter		yes
Make thyroid blocking in PAZ and		yes
Monitor UAZ and take action where OILs are		yes
Restrict fresh food and		yes
Notify nearby		yes
Examine/counsel exposed for follow up		yes

III- 34

AFTER THE START OF RELEASE REVISE PROTECTIVE BASED ON ENVIRONMENTAL MEASUREMENTS

•BSS Recommended Guidance (IAEA, WHO, FAO, ILO, NEA (OECD), PAHO)
  -Generic Intervention Levels (GIL)
  -Generic Action Levels (GAL)

•Criteria for
  -Urgent Actions (e.g., evacuation)
  -Long-term Actions (e.g., Relocation)
  -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

III- 35

The BSS GILS AND GALS CAN NOT BE USED DIRECTLY DURING ACCIDENT

•Not directly readable on instrument
•Develop operational intervention levels (OIL) as part of planning
•OIL readable on instruments used
•OIL used during accident to make decisions
•IAEA has developed suggested default OILs
•Revise defaults during accident

III- 36

GAMMA DOSE RATE MEASUREMENTS
IN ENVIRONMENT

- Most important environmental monitoring
- Easy to measure with simple instrument and little training
- Can use to decide where to:

  evacuate
  shelter
  give thyroid blocking
  relocate

III-37

DEFAULT GROUND GAMMA DOSE RATE OILS FOR EVACUATION -- AN EXAMPLE

$$\frac{50mSv}{168h} \times \frac{1}{0.5} \times \frac{1}{0.5} \cong 1mSv/h$$

50 mSv	**Evacuation GIL**
168 h	**Hours in 7 days**
0.5	**Dose reduction due to normal activity**
0.5	**Dose reduction due to decay**

III-38

DEFAULT GAMMA DOSE RATE OILS

1.0 mSv/h (100 mR/h) - Evacuate

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

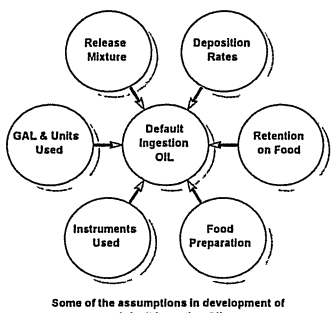
0.1 μSv/h (10μR/h) - Typical Background

III-39

CROP AND MILK OIL S

- Gamma dose rate OIL inadequate
- Use deposition concentration
- Used to determine areas where restrictions should be considered or relaxed
- Use marker (single) isotope - faster
- Based on assumptions of release mix

III-40



Some of the assumptions in development of default ingestion OIL

III-41

DEPOSITION MARKER ISOTOPE OILS
TO RESTRICT FOOD PRODUCED IN CONTAMINATED AREA

10 kBq/m2 - I-131 food

2 kBq/m2 - I-131 milk

2 kBq/m2 - Cs-137 food

10 kBq/m2 - Cs-137 milk

III-42

FOOD CONCENTRATIONS OILS

1 Bq/kg - I-131 in food

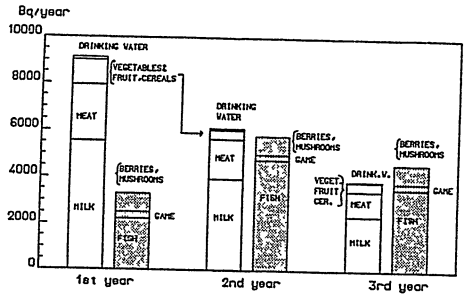
0.1 kBq/kg - I-131 in milk, water

0.2 kBq/kg - Cs-137 in food

0.3 kBq/kg - Cs-137 in milk, water

III- 43

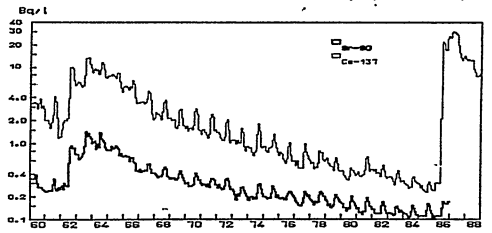
LONGER TERM INGESTION PATHWAYS IN FINLAND AFTER CHERNOBYL



III- 44

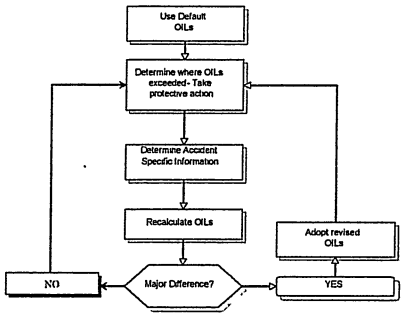
FINLAND
CS-137 AND SR-90 IN MILK

- Note seasonal variations and levels in test days (1962 - 1964)



III- 45

USE OF OILS



III- 46

EMERGENCY WORKERS

31 received lethal doses at Chernobyl (early deaths)

- On-site personnel and off-site fire brigade
- Inhalation, external and skin contamination all important sources of dose
- Did not monitor their dose
- Were not trained
- Did not have adequate protective equipment

III- 47

FIRST HOUR SCHEDULE FOR SEVERE ACCIDENT

Event detected by control room (0.00)

classified and emergency is declared (+ 5 min)

Off-site officials notified (+ 15 min)

Off-site officials decide on action (+ 30 min.)

Sirens sound and the 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 minutes

Extensive environmental monitoring begun

Additional actions taken at levels consistent with International guidance

III- 48