Radiation Dose Assessment in Nuclear Emergencies

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Objectives

- Radiation dose assessment immediately following an emergency
- Methods to determine radiation dose to individuals after emergency

Immediately after Accident

- Focus on preventing acute radiation effects to individuals.
- Contamination issues are a secondary concern, especially when the contaminated incident site and number of evacuees is large.
- Individuals with *spot* contamination greater than 2.2×10^6 dpm (37,000 Bq) should be a priority for decontamination

Immediately after Accident

Nausea and vomiting are the earliest clinical signs of acute radiation syndrome (ARS).

Nausea and vomiting are symptoms that occur as whole-body absorbed doses become

high [i.e., >100 rad (>1 Gy)].

Short-Term Whole-Body Dose [rad (Gy)]	Acute Death[b] from Radiation Without Medical Treatment (%)	Acute Death from Radiation with Medical Treatment (%)	Acute Symptoms (nausea and vomiting within 4 h) (%)	Lifetime Risk of Fatal Cancer Without Radiation Exposure (%)	Excess Lifetime Risk of Fatal Cancer Due to Short-Term Radiation Exposure[c] (%)
1 (0.01)	0	0	0	24	0.08
10 (0.1)	0	0	0	24	0.8
50 (0.5)	0	0	0	24	4
100 (1)	<5	0	5 – 30	24	8
150 (1.5)	<5	<5	40	24	12
200 (2)	5	<5	60	24	16
300 (3)	30 – 50	15 – 30	75	24	24[d]
600 (6)	95 – 100	50	100	24	>40[d]
1,000 (10)	100	>90	100	24	>50[d]

Criticality Accident

Radiation dose reading in armpit after criticality accident neutron exposure

$$\text{Dose in Gy} = \frac{3.5 \cdot x\,\frac{\mu\text{Gy}}{\text{h}}}{\text{mass in kg}}$$

Example

Induced ^{24}Na activity expected after fast neutron exposure to 0.04 Gy of fast neutrons

Mass in kg	Count rate immediately following exposure (cpm)	Count rate 15 minutes after exposure (cpm)
70	275	135
80	310	155
90	350	175
100	400	200

Criticality Accident

Fast neutron dose based on ^{32}P activation in hair

(See IAEA Technical Report Series 152 for sample preparation)

$$D = 0.55\,A$$

A = ^{32}P activity (dpm per gram of hair)

D = dose in Gy

Rule of Sevens and Tens

- After exposure rates have begun to decrease, for every seven-fold increase in time after detonation of a nuclear weapon, there is a ten-fold decrease in exposure.

Example

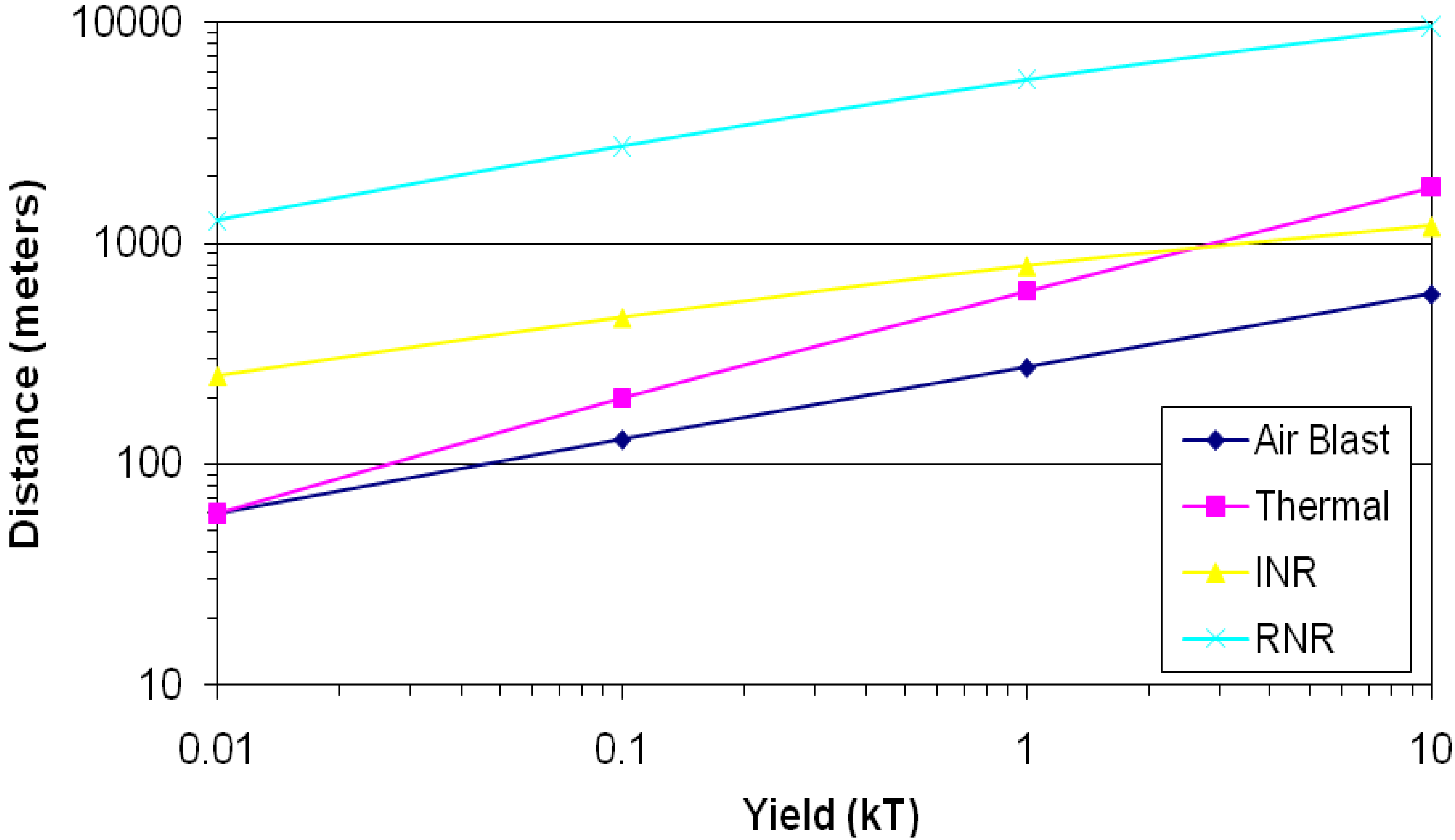
Time in hours	Fraction decrease	Radiation Intensity Gy/h
1	-	1000
7	1/10	100
49	1/100	10
343	1/1000	1

Example

50 Gy/h radiation dose rate at three hours after detonation

After 21 hours, radiation dose will be 5 Gy/h

After 147 hours, radiation dose will be 0.5 Gy/h.



Distance to LD50 Initial Nuclear Radiation (INR), Residual Nuclear Radiation (RNR)

Dose in Gy in Frist Hour After Detonation

Detonation yield (kt)	1000 m	2000 m	10,000 m
0.01	6.7	1.5	0.001
0.1	38	8.3	0.1
1	210	47	0.6
10	1200	260	3.5

Radiation Dose by Injury

Radiation Dose in Gy		Time to Onset
3	Temporary hair loss	14-21 days
6	Skin Erythema	Transient then secondary erythema, 14-21 d
10-15	Skin Dry desquamation	>21 days
>20	Neurovascular syndrome	Minutes (death in 24-48 h)
20-50	Skin wet desquamation	2-3 weeks

Biological Radiation Dosimeters

- Pseudo Pelger Huet Cell Anomaly
  - Still experimental
  - Thought to demonstrate linear response to all types of ionizing radiation exposure
  - Requires a blood smear
  - Can be used to quickly sort
- Count lymphocyte acentric/dicentric in blood
  - Well established method
  - Measures >0.2 Sv

Dose, Gy	% emesis	Median onset of emesis (h)	Absolute lymphocyte count; % of normal in first 24 h	Relative increase in serum amylase, day 1	Number of dicentrics per 50 metaphases
0	-	-	100	1	0.05–0.1
1	19	-	88	2	4
2	35	4.6	78	4	12
3	54	2.6	69	6	22
4	72	1.7	60	10	35
5	86	1.3	53	13	51
> 6	90–100	1.0	< 47	> 15	-

Inhalation Radiation Dose

- Nasal swabs – assume estimate 5-10% of intake, may be as high as 25%
  - Not a good quantitative predictor, qualitative yes
- Bioassay
  - In vivo using NaI or HPGe
  - In vitro using urine or fecal analysis

Electron Spin Resonance (ESR)

- Useful for external gamma ray doses above 0.5 Sv
- Requires crystal matrix materials
  - Tooth, watch crystal, some building materials
- Complex, time consuming

Inverse Square Dose Estimate

- Photon measurements

$$I_1 d_1^2 = I_2 d_2^2$$

- I_1 = Radiation intensity at location 1
- I_2 = Radiation intensity at location 2
- d_1 = distance from location 1 to radiation source
- d_2 = distance from location 2 to radiation source

Example

- The radiation dose rate from a radiation sources is 0.05 Gy/h at a distance of 10 meters. A person was standing at 2 meters from the source for 1 hour. What is the radiation dose?

Inverse Square Dose Estimate

$$I_1 d_1^2 = I_2 d_2^2$$

- I_1 = 0.05 Gy/h
- I_2 = Radiation intensity at location 2
- d_1 = 10 m
- d_2 = 2 m

$$0.05 \text{ Gy/h } (10 \text{ m})^2 = I_2 (2 \text{ m})^2$$

I_2 = 1.25 Gy/h

1.25 Gy/h for 1 hour = 1.25 Gy

References

Colorado State University

- NCRP Commentary 19, Key Elements of Preparing Emergency Responders for Nuclear and Radiological Terrorism
- IAEA Evaluation of Radiation Emergencies and Accidents, Technical Report Series 152
- Health Physics and Radiological Health 4th Edition