Outline of the OSCAAR and the Application to Nuclear Emergency Planning

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* Off-Site Consequence Analysis of Atmospheric Releases of radionuclides

Background

- **IAEA Safety Requirements (GS-R-2, 2002)**
  Safety Standards (GSG-2, 2011)
  - Management approach emphasizes planning to respond effectively to achieve the goals, rather than simply responding to a situation
  - Criteria for initiating protective actions and criteria to support decision-making in a nuclear emergency
- **ICRP (Publ.109, 2008)**
  - Optimization of the overall protection strategy
- **NRA (Nuclear Emergency Response Guidelines, 2012)**
  - After Fukushima accident, emergency preparedness measures were strengthened
    - EAL and OIL for decision-making in a nuclear emergency
    - PAZ (-5 km) and UPZ (-30 km), the area for implementing urgent protective actions
  - No information on practical strategies for urgent protective actions

Objectives

- Perform a risk informed analysis of protective measures using Level 3PRA code, OSCAAR, to formulate the technical basis for the effective emergency planning
  - Evaluate the combination of effects of urgent protective actions (sheltering, evacuation and iodine thyroid blocking)
  - Introduce a metabolic model of iodine to OSCAAR, evaluating the effect of reducing thyroid dose by the timing of taking of stable iodine

Outline of OSCAAR

OSCAAR modules

Radionuclide Concentration
- Air
- Ground

Dose
- Equivalent doses
- Effective dose

Early protective action model (sheltering, evacuation and iodine thyroid blocking)

Level2 PRA

Source terms

Deposition

Atmospheric Dispersion Gaussian puff trajectory model

Dose Evaluation for Chronic Exposure

Dose Evaluation for Early Exposure

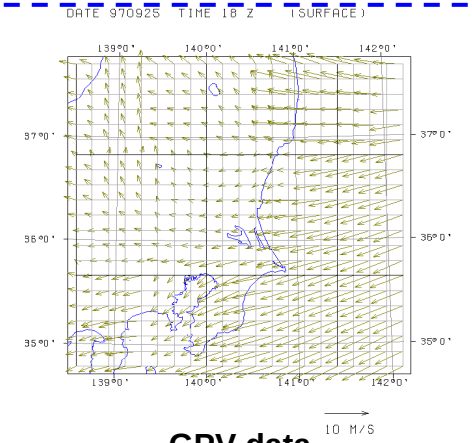
Population And Agricultural data

Early and Late Protective Actions

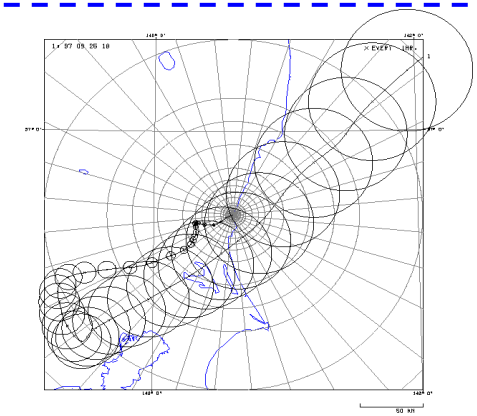
- **Health Effect**
- **Economic Loss**

Metrological Data

- GPV (Grid Point Values) data by Japan Meteorological Agency
- Metrological Sampling (specify weather condition, stratified random sampling, weather bin sampling)

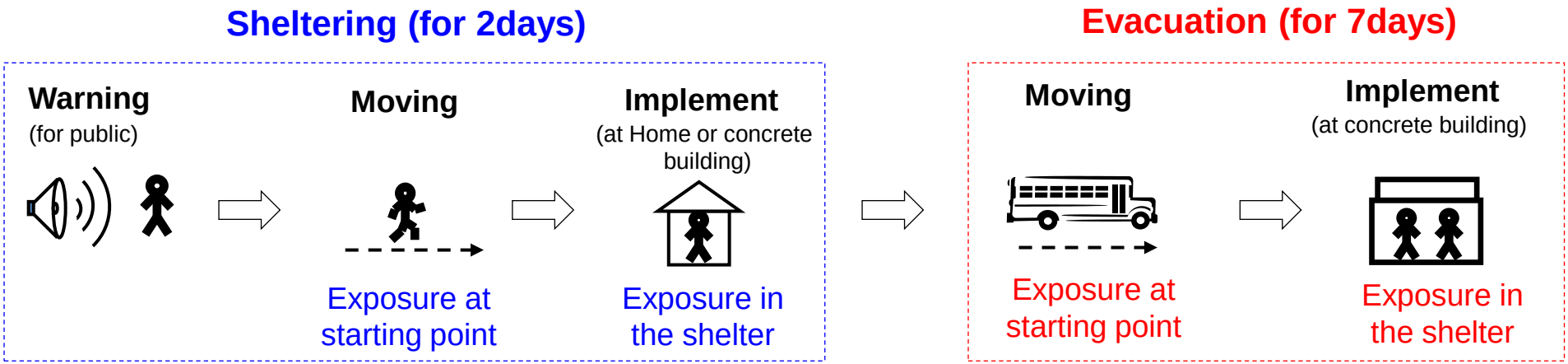


GPV data



Gaussian puff trajectory model

Early protective action model
- Sheltering and Evacuation -



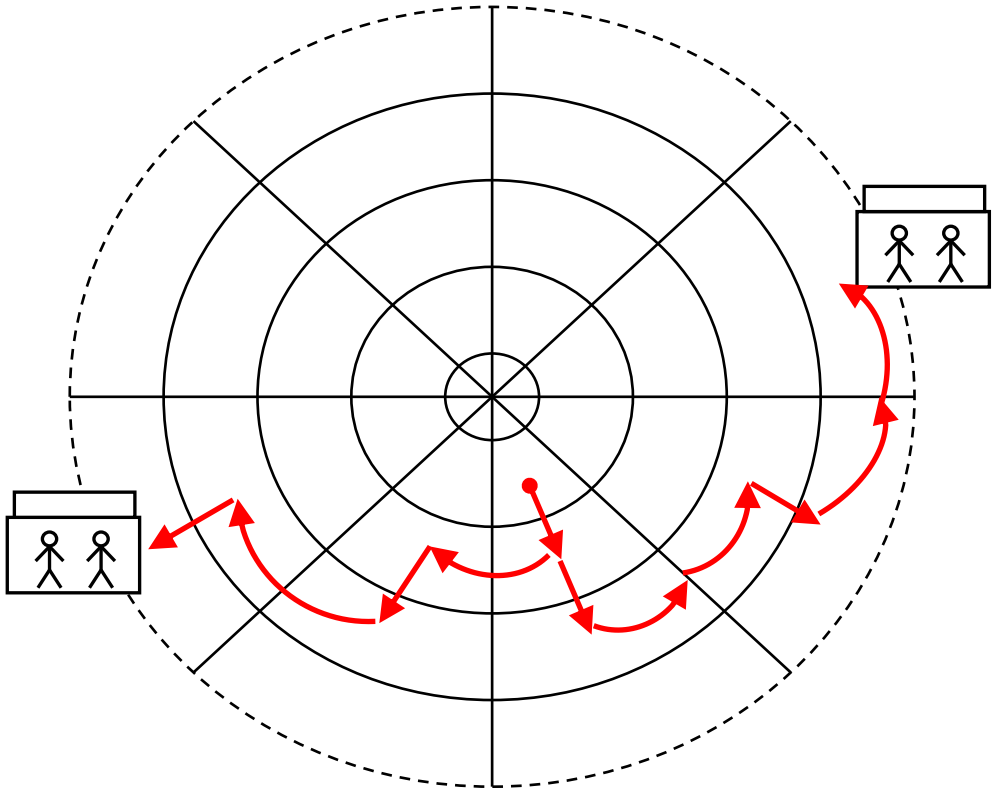
- Evaluation parameters

Protective action	Shielding factor*	Inhalation Protection factor*	Area	Preparation time
Sheltering at home	• 0.9 (Cloudshine) • 0.4 (Groundshine)	0.25	Each spatial element	1 hour
Sheltering in concrete building	• 0.6 (Cloudshine) • 0.2 (Groundshine)	0.05	Each spatial element	1 hour
Evacuation	—	—	Move to concrete building at 30 km from release point	• 8 hours (- 5km) • 6 hours (5-10km)

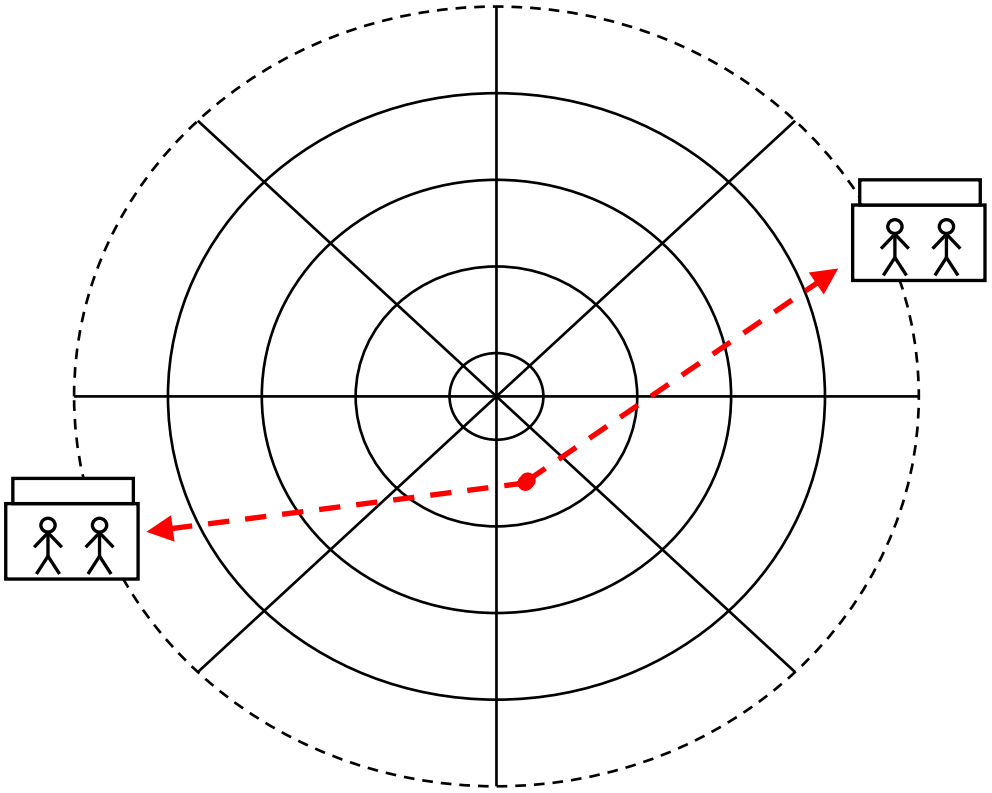
* The emergency preparedness guidelines ”Emergency preparedness of nuclear installations”, NSC (2010).

Early protective action model
- Evacuation -

- **MACCS2 (Network model)**



- **OSCAAR**

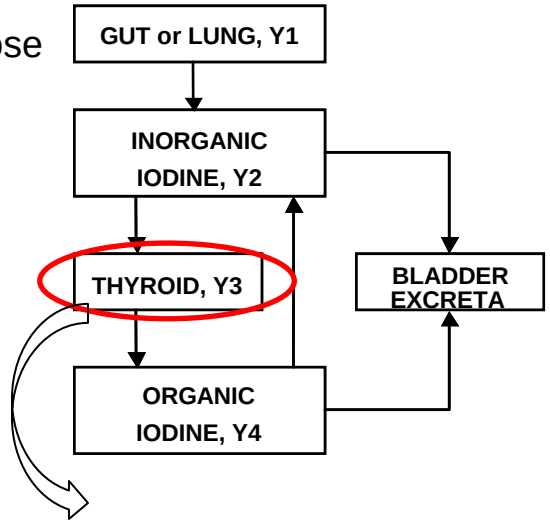


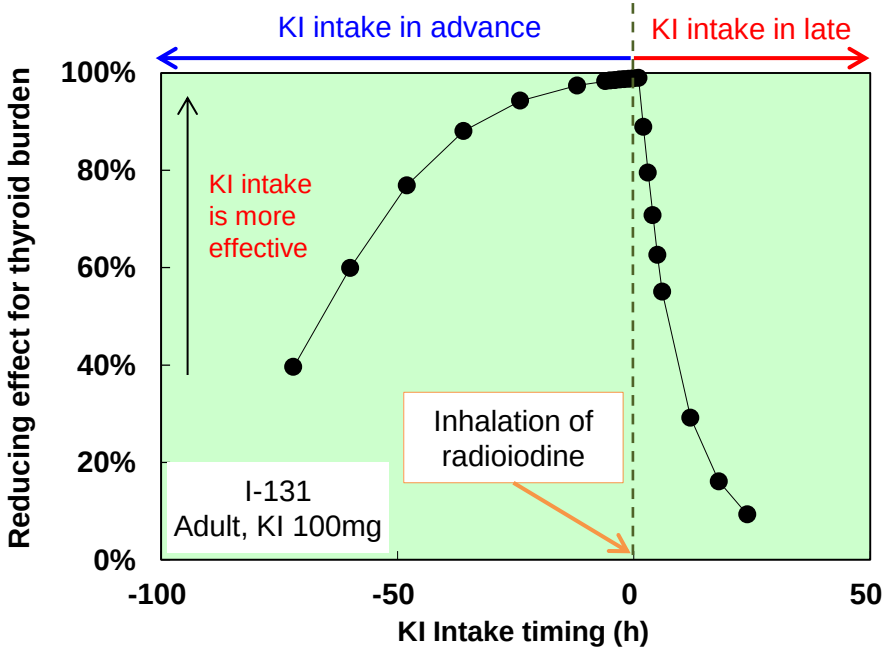
- OSCAAR user specifies the destination point by each spatial element.
- OSCAAR assumes the evacuee moves instantly from the starting point to the destination point (conservative evaluation).

Early protective action model
- Iodine thyroid blocking -

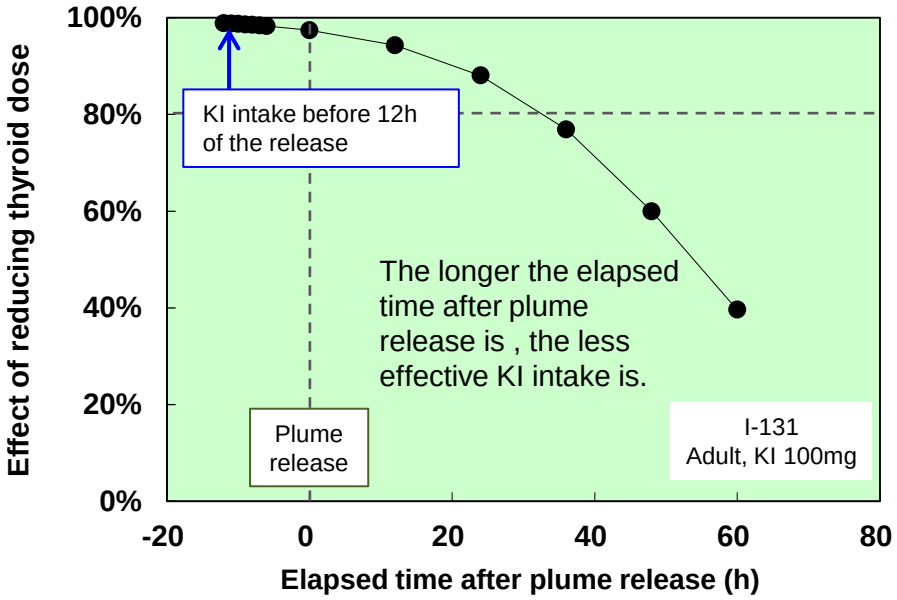
Effect of reducing thyroid dose depends on timing of stable iodine (KI) intake

- The metabolic model of iodine* can evaluate the effect of KI intake.
- This model applies to OSCAAR.





Effect of reducing thyroid dose for the time of the plume passage



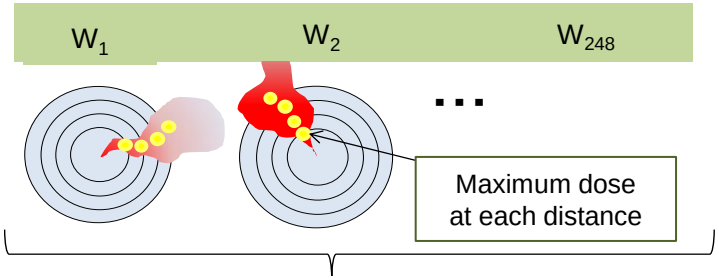
- Our study assumed that KI intake for all of the area is implemented simultaneously before12h of plume release.
- The effect of reducing thyroid dose depends on the area because the time of the plume passage differs by the distance from the release point.

*J. R. Johnson (1981). “Radioiodine Dosimetry”, Journal of Radioanalytical Chemistry, 65, 223-238.

Application to nuclear emergency planning - Evaluation method -

- Analysis condition
  - 1,100MWe model plant
  - Weather sequences:
    248 of 8760 (using stratified sampling method)
  - Exposure pathways:
    Cloudshine, Groundshine, Inhalation
  - Exposure duration:
    7days

Weather sequences

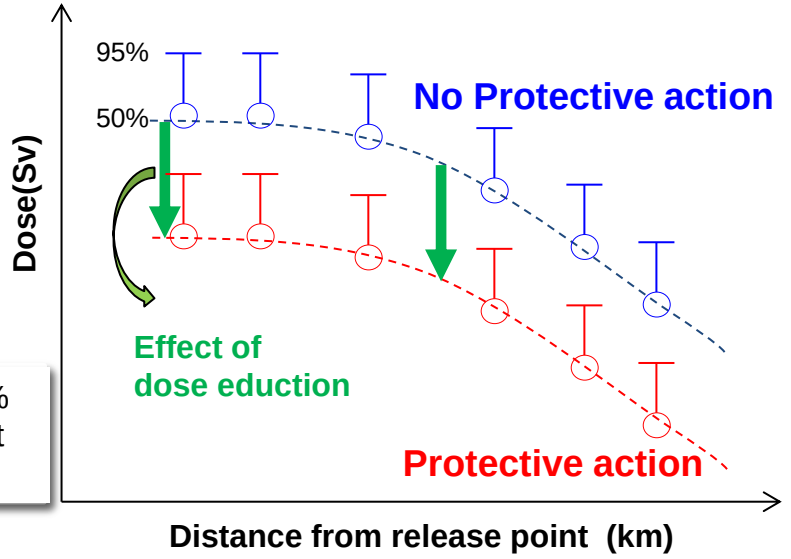


Select maximum dose from 248 weather sequences

	W_1	W_2	⋯	W_{248}
d_1	51 mSv	103 mSv	⋯	98 mSv
d_2	21 mSv	61 mSv	⋯	55 mSv
⋮	⋮	⋮		
d_n	11 mSv	23 mSv		31 mSv

Select 50 and 95% values of doses at each distance

- Evaluation for the effect of protective action



- The effect of protective actions depends on progress of the accident and the timing of implementing them.
- It is important to implement effective protective actions at each distance.

Effective protective actions for nuclear emergency planning was evaluated for accident scenarios.

Application to nuclear emergency planning - Source Terms -

▪ Release fraction

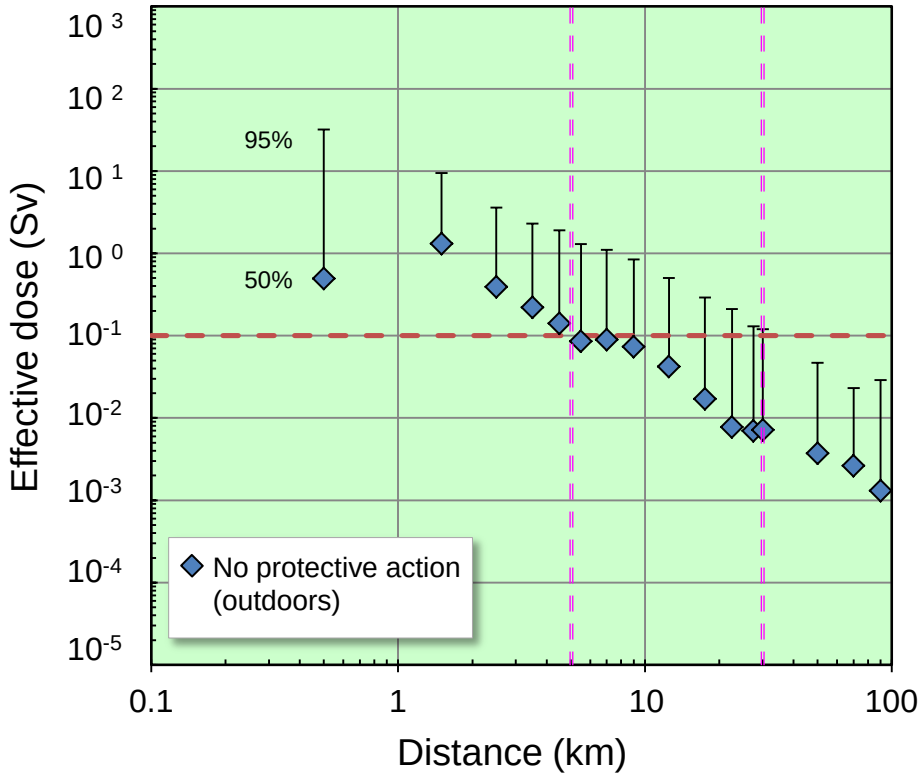
Accident scenario	Xe	Org. I	I	Cs	Te	Ba	Ru	La
Our study*								
Large late release	9.5E-01	1.6E-03	3.1E-02	2.8E-02	2.8E-04	1.2E-08	2.4E-11	5.2E-12
Control release	8.7E-01	4.5E-05	8.6E-04	7.5E-04	3.2E-04	2.0E-08	3.4E-11	6.5E-12
Ref. Fukushima accident**								
Unit 1	9.5E-01	—	6.6E-03	2.9E-03	1.1E-02	4.0E-05	9.0E-10	1.2E-07
Unit 2	9.6E-01	—	6.7E-02	5.8E-02	3.0E-02	2.6E-04	5.4E-10	8.4E-07
Unit 3	9.9E-01	—	3.0E-03	2.7E-03	2.4E-03	4.3E-04	8.6E-10	1.3E-07

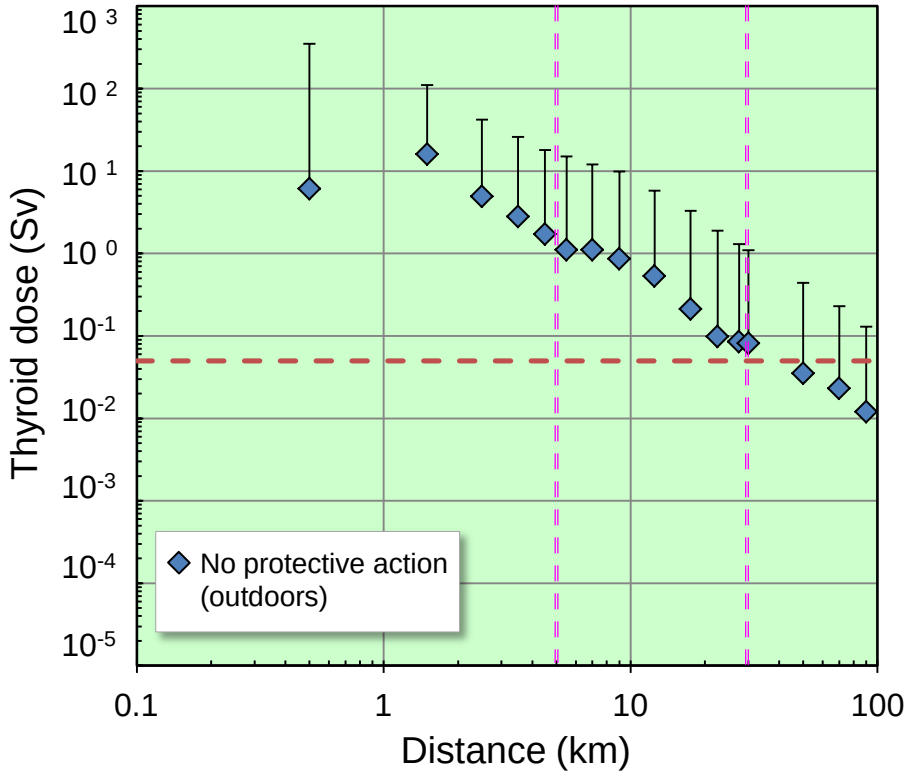
▪ Release time and height

	Large late release	Control release	Fukushima accident*		
			Unit1	Unit2	Unit3
Release time after scram	27h	12h	about 20h	about 80h	about 40h
Release duration	7h	22h	—	—	—
Release height	0, 40 m***	100 m	—	—	—

* The analysis result is derived from JAEA's severe accident study using a Level 2 PSA code, THALES.
** Report of Japanese Government to the IAEA Ministerial Conference on Nuclear Safety - The Accident at TEPCO's Fukushima Nuclear Power Stations -
*** It assumes multiple release from the NPP. The release height is different by each release phase.

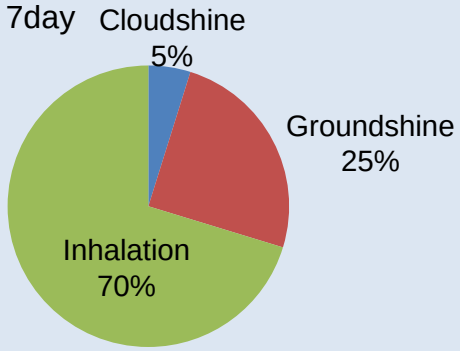
Projected dose for large late release scenario



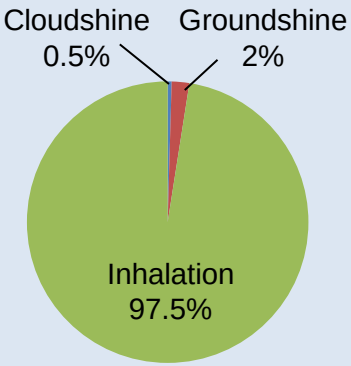


Contribution from exposure pathways to doses at 10 km point

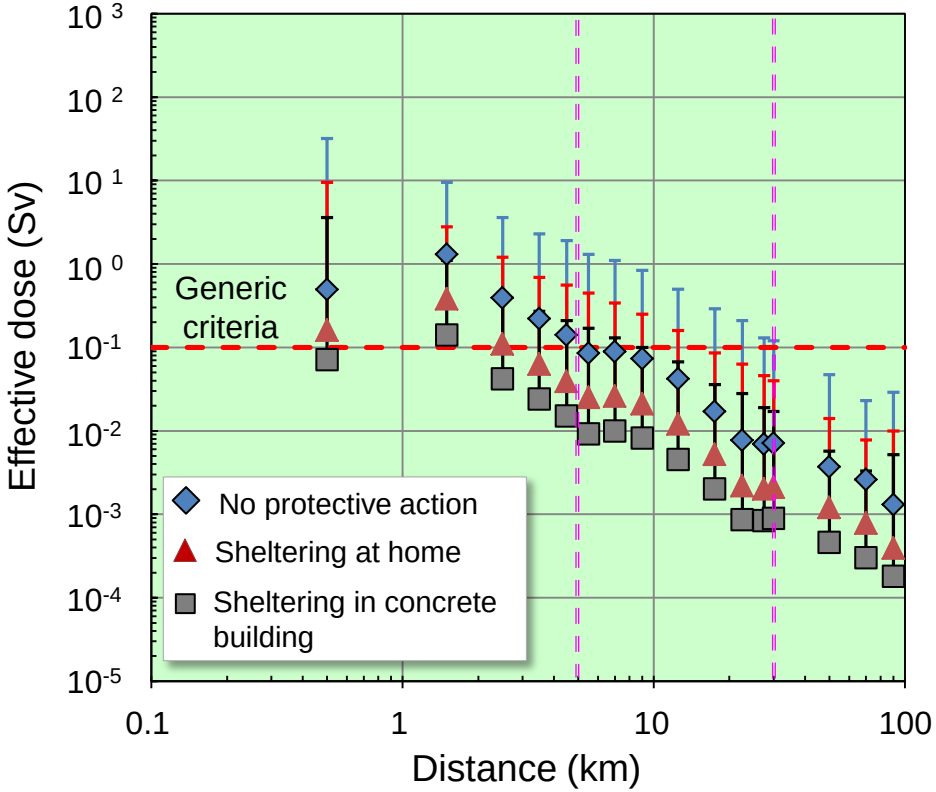
Effective dose for 7day

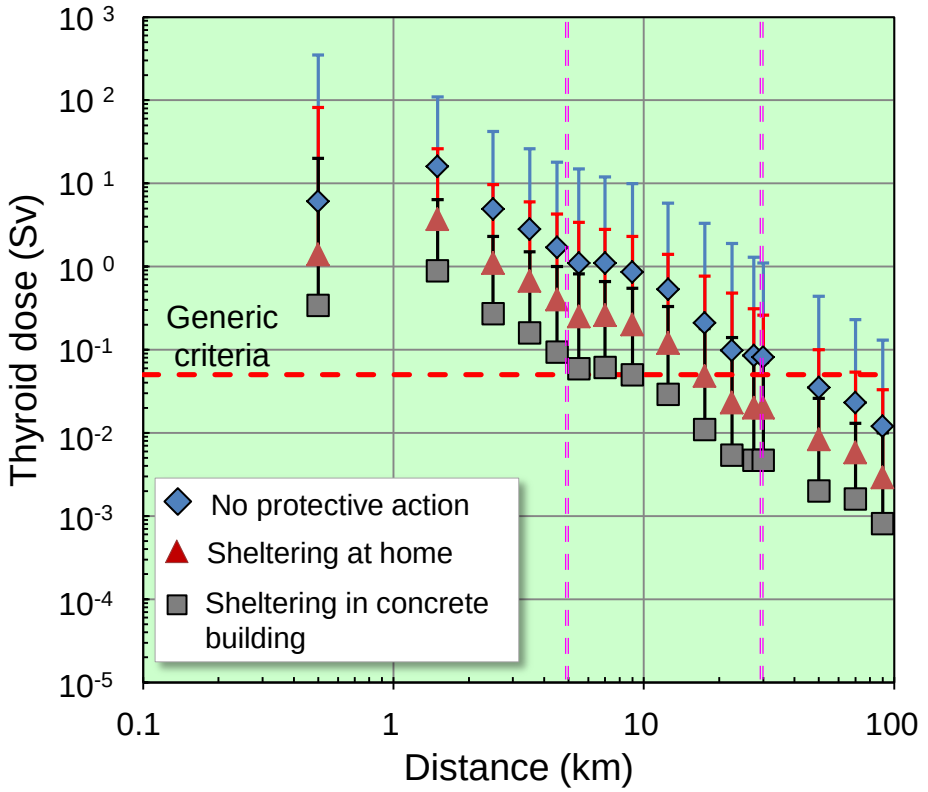


Thyroid dose for 7days



Individual protective action for large late release scenario

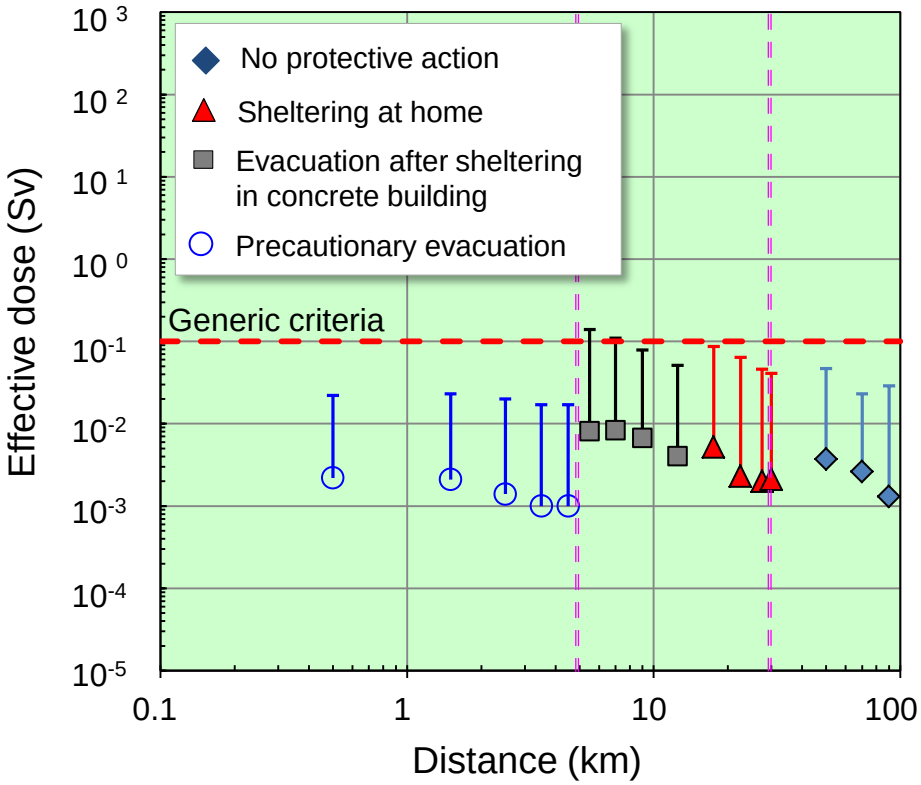


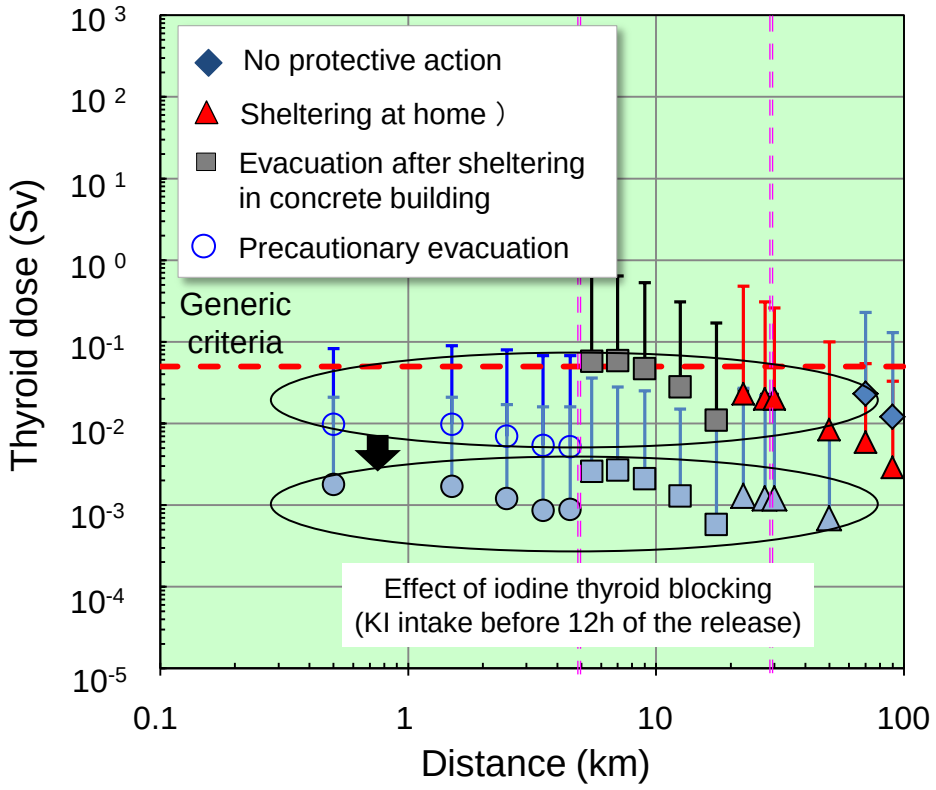


- The effective dose for sheltering at home or in concrete building is estimated to 0.3 or 0.1 times of that for no protective action.
- The 95% value of effective or thyroid dose for these protective actions exceeds the generic criteria* within 30km area.

* IAEA GSG-2 shows generic criteria for urgent protective actions as follows.
- Sheltering and evacuation: 100mSv of effective dose in the first 7days
- Iodine thyroid blocking: 50mSv of thyroid dose in the first 7days

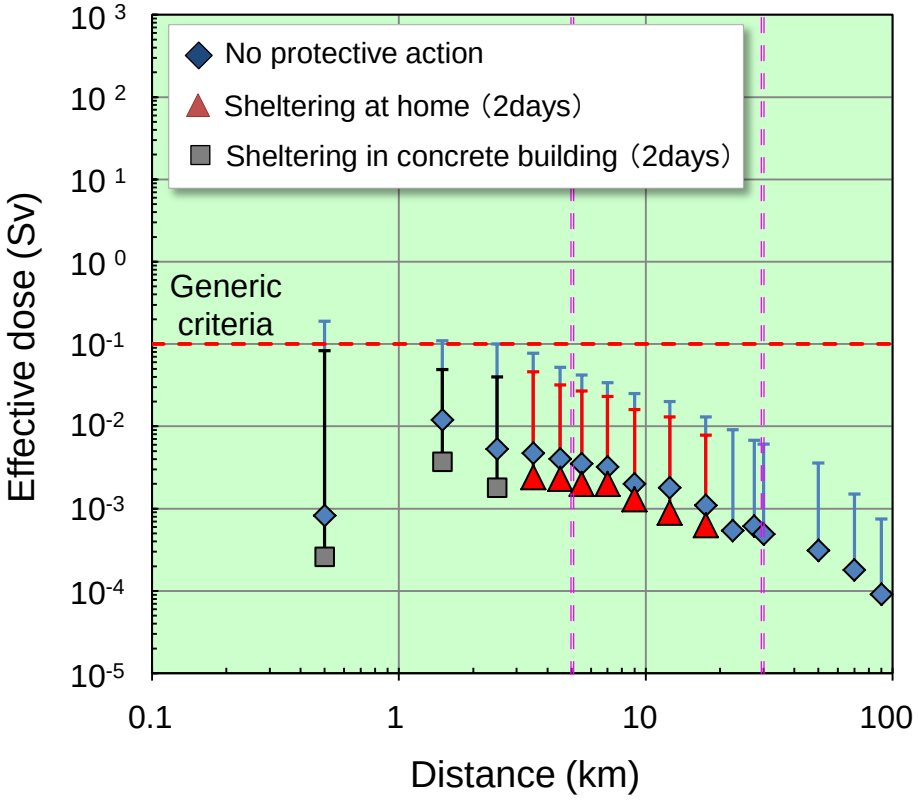
Combined protective actions for large late release scenario

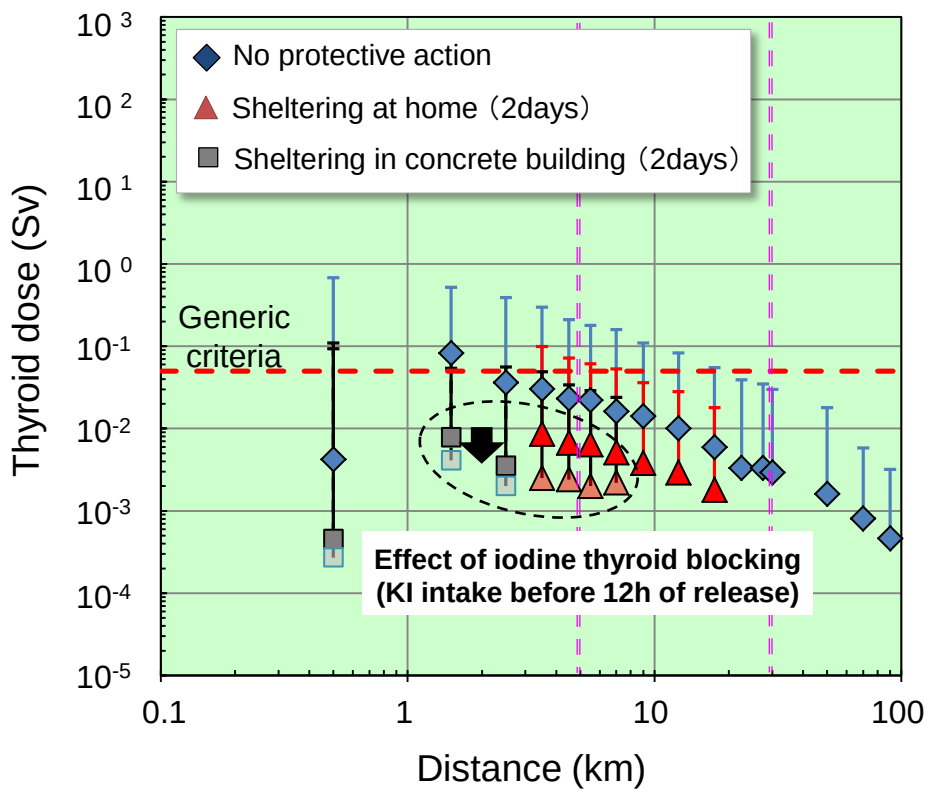




- The effective dose can be reduced below 100 mSv by implementing combined protective actions as follows.
  - ✓ - 5 km: Precautionary evacuation
  - ✓ 5-15 km: Evacuation after sheltering in concrete building
  - ✓ 15-30 km: Sheltering at home
- The thyroid dose can be reduced below 50 mSv by implementing these protective actions with iodine thyroid blocking within 30 km.

Combined protective actions for control release scenario





- If no protective action is implemented, the effective and thyroid doses have possibilities to exceed generic criteria.
- Therefore, sheltering at home or in concrete building with iodine thyroid blocking is effective.

Summary

- Perform a risk informed analysis of protective measures using the OSCAAR to formulate the technical basis for the effective emergency planning
  - Combination of protective measures, sheltering and evacuation with administration of stable iodine

- Application to nuclear emergency planning
  - **Large late release scenario**
    - Precautionary evacuation before the release is the effective protective action within 5km.
    - The effective dose can be reduced by implementing evacuation after sheltering in concrete building in 5-15km and sheltering at home in 15-30km.
    - Iodine thyroid blocking before the release is the effective protective action within 30km to reduce thyroid dose.
  - **Control release scenario**
    - Under almost all of weather condition, effective and thyroid doses are below the generic criteria of the IAEA.
    - Sheltering with iodine thyroid blocking is effective.