Document No.1-3

The Results of Radioactive Material Dispersion Impact Assessment at Kashiwazaki-Kariwa Nuclear Power Station

December 16, 2015

東京電力
TEPCO

- Out of regret as the main party responsible for the accident at the Fukushima Daiichi Nuclear Power Station, TEPCO has continued to advance improvements in our effort to enhance the safety of the Kashiwazaki-Kariwa Nuclear Power Station.
- Improvements have been implemented so as to avoid PCV venting by alternative cooling facilities, to extend venting time based on operational improvements, and to install iodine filters.
- To further improve safety in the future, we will continue our constant efforts, and, if an accident should occur, we intend to provide the maximum support for evacuation to ensure the safety of all residents.
- Accordingly, an assessment is to be conducted of the impact from radioactive material dispersion to achieve the following objectives.
  - ✓ To verify the effectiveness of safety measures adopted at the Kashiwazaki-Kariwa Nuclear Power Station
  - ✓ To study measures to support the evacuation of residents
- A radioactive material dispersion impact assessment is to be conducted in Niigata Prefecture as well.

(Announced on September 10, 2015)

Flow diagram of assessment

Postulated accident case → **Assessment of radioactive material release rate** → **Dispersion impact assessment** → **Assessment results feedback**

✓ Verify effectiveness of safety measures
✓ Study measures to support evacuation of residents

- Today, the results of dispersion impact assessment without the effects of evacuation (the assessment of staying at the same place outdoor) is explained.
- TEPCO keeps studying assessment with the effects of evacuation and measures to support all residents.

1. Accident Cases Assumed

■ The venting after 38 hours scenario currently being assessed as part of the Nuclear Regulation Authority's regulatory licensing review was selected as a base case.
■4 Niigata Prefecture assessment cases were also selected for comparison.

Assessment case	Safety functions: Cooling water injection – Design basis-response facilities	Safety functions: Cooling water injection – Severe accident response facilities	Safety functions: FV	Pressure vessel damage	Containment vessel damage	Time until release commenced	Regulatory licensing review	Niigata Prefecture	TEPCO
[Base case] Venting after 38 hours scenario (regulatory licensing review scenario: ① assessment conditions revised)	×	○ Permanent equipment	○	**No**	**No**	**38h**	○	— ※3	○

<Comparison> Cases selected by Niigata Prefecture

Assessment case	Design basis-response facilities	Severe accident response facilities	FV	Pressure vessel damage	Containment vessel damage	Time until release commenced	Regulatory licensing review	Niigata Prefecture	TEPCO
①Venting after 25 hours venting scenario (Major LOCA※1＋loss of all emergency cooling system functionality＋station black out)	×	○ Permanent equipment	○	No	No	25h	— ※2	○	○
②Venting after 18 hours venting scenario (Loss of high and low pressure functionality ＋station black out＋inability of fire engines to inject cooling water into reactor)	×	○ Fire engine	○	Yes	No	18h	—	○	○
③Venting after 6 hours case (no scenario)	×	×	○	Yes	No	6h	—	○	○
④【Reference case】 (Case where cooling water injection function is not taken into account and the PCV is damaged such that radioactive material is released without passing through a filtered vent.)	×	×	×	Yes	Yes	8h	—	○	○

※1: LOCA: Loss-of-coolant accident, ※2: Previous scenario at time of establishment permit application
※3: Already explained in the 4th technical committee in 2015 (March 24, 2015)

2. Assessed Release Amounts of Radioactive Materials into the Air in Each Simulated Accident Case

Release Amount (Bq) *1		Noble gas (0.5MeV conversion)	Iodine (Iodine 131 equivalent dose)*2				Cesium 134	Cesium 136	Cesium 137*4
			Particle	Inorganic	Organic	Total*3			
[Base case] Venting after 38 hours scenario	**After 38 hours**	**1.01×10^{18}**	**4.47×10^{9}**	**2.17×10^{8}**	**1.34×10^{10}**	**1.81×10^{10}**	**1.38×10^{9}**	**3.44×10^{8}**	**1.13×10^{9}**

<Comparison> Cases selected by Niigata Prefecture

①Venting after 25 hours venting scenario	After 25 hours	1.63×10^{18}	2.49×10^{10}	1.21×10^{9}	1.49×10^{11}	1.76×10^{11}	2.69×10^{9}	7.00×10^{8}	2.19×10^{9}
②Venting after 18 hours venting scenario	After 18 hours	2.03×10^{18}	1.03×10^{12}	5.02×10^{10}	3.10×10^{10}	1.12×10^{12}	5.77×10^{10}	1.53×10^{10}	4.69×10^{10}
③Venting after 6 hours case (no scenario)	After 6 hours	4.50×10^{18}	1.21×10^{12}	5.87×10^{10}	3.63×10^{10}	1.31×10^{12}	5.77×10^{10}	1.57×10^{10}	4.69×10^{10}
④【Reference case】 CV damaged by over heat	After 8 hours	3.66×10^{18}	2.87×10^{16}	5.23×10^{17}	2.30×10^{16}	5.75×10^{17}	8.89×10^{15}	1.92×10^{15}	7.07×10^{15}

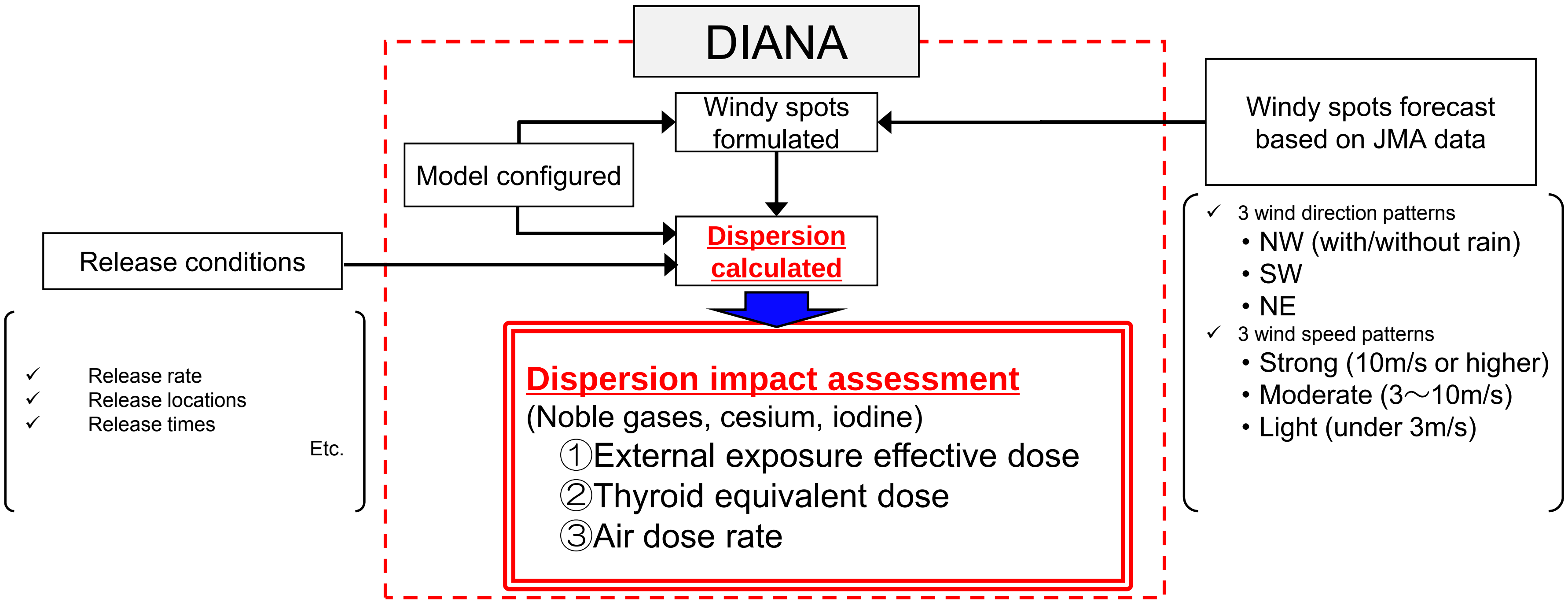
*1. The values of Release Amount are the ones which are rounded off to four significant digits. (the total amounts in 72 hours after venting operations)
*2. Iodine-131, -132, -133, -134 and -135 are each converted into Iodine-131, and added up together.
*3. "Total" means the total amount of particulate iodine, inorganic iodine and organic iodine.
*4. It has been confirmed that the release amount of Cecium-137 is, except for "Reference case," less than 1 x 10^{14} (100 tera) Bq, the value which is stated in the Guideline for Verification of Effectiveness of Reactor Core Damage Prevention Measures and PCV Damage Prevention Measures of Commercial Nuclear Power Reactors.

■ TEPCO's proprietary DIANA system is used to conduct assessments of the impact of radioactive material dispersions.

What is DIANA?

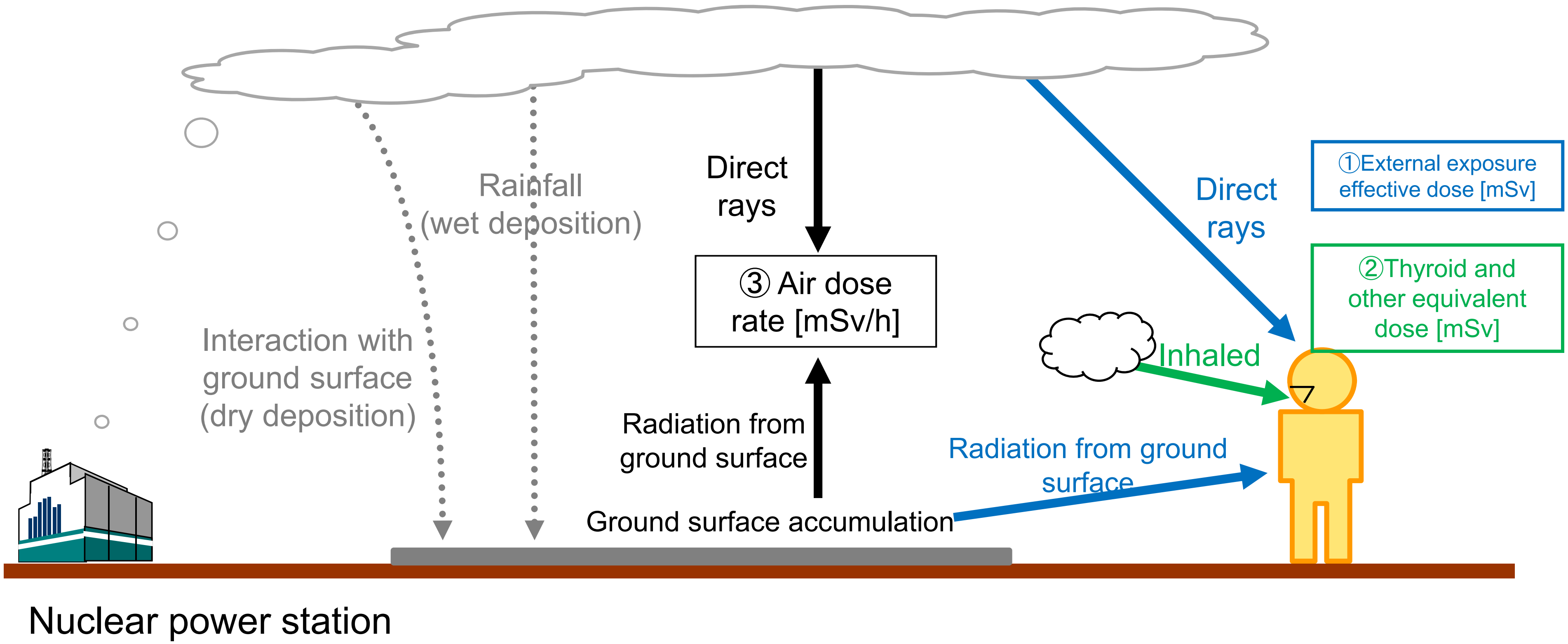
■ DIANA is a system for calculating the dispersion of radioactive materials based on given input data.

■ The calculations allow for a variety of operations to be performed and radiation levels (rates) to be output for each chronological point



DIANA(Dose Information Analysis at Nuclear Accident): System for predicting and assessing radiation levels around nuclear power stations

■ Based on input release and meteorological conditions, the DIANA system for the dispersion impact assessment computes the effective dose, thyroid and other such equivalent dose, and the air dose rate due to radiation from direct rays and ground surface that originates from radioactive materials released during an accident.



①External exposure effective dose [mSv]: radiation external exposure from direct rays and ground surface
②Thyroid and other equivalent dose [mSv]: internal exposure through inhalation
③Air dose rate [mSv/h]: radiation dose from direct rays and ground surface per unit of time

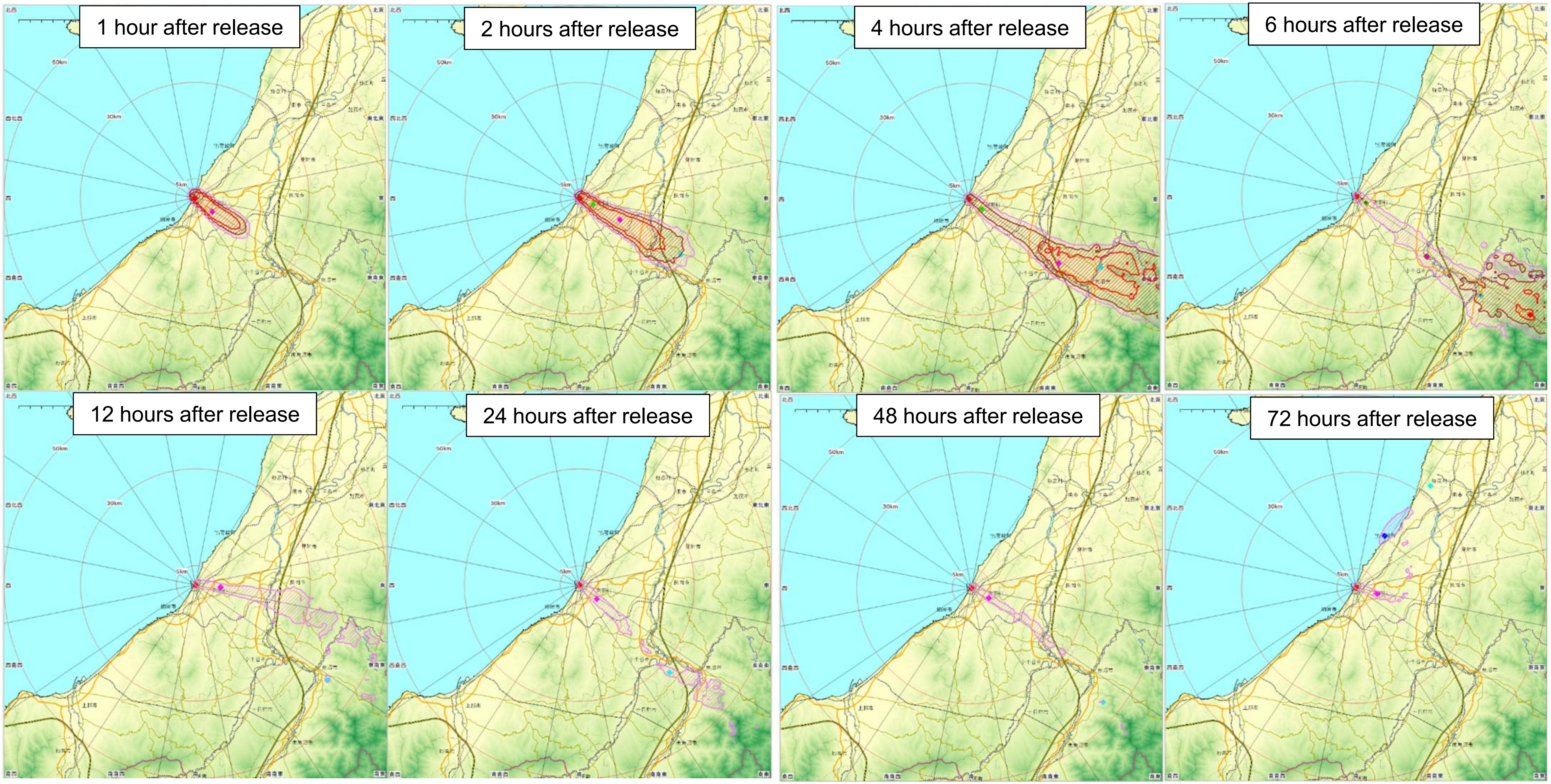
[Base Case] with filter vent
Venting after 38 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 38 hours scenario (with filter vent)
Nuclide	noble gas, iodine, Cesium

Isogram: Air Absorbed Dose Rate

- 5.0E+02 ～ μGy/h
- 2.0E+01 ～ 5.0E+02 μGy/h
- 5.0E-01 ～ 2.0E+01 μGy/h



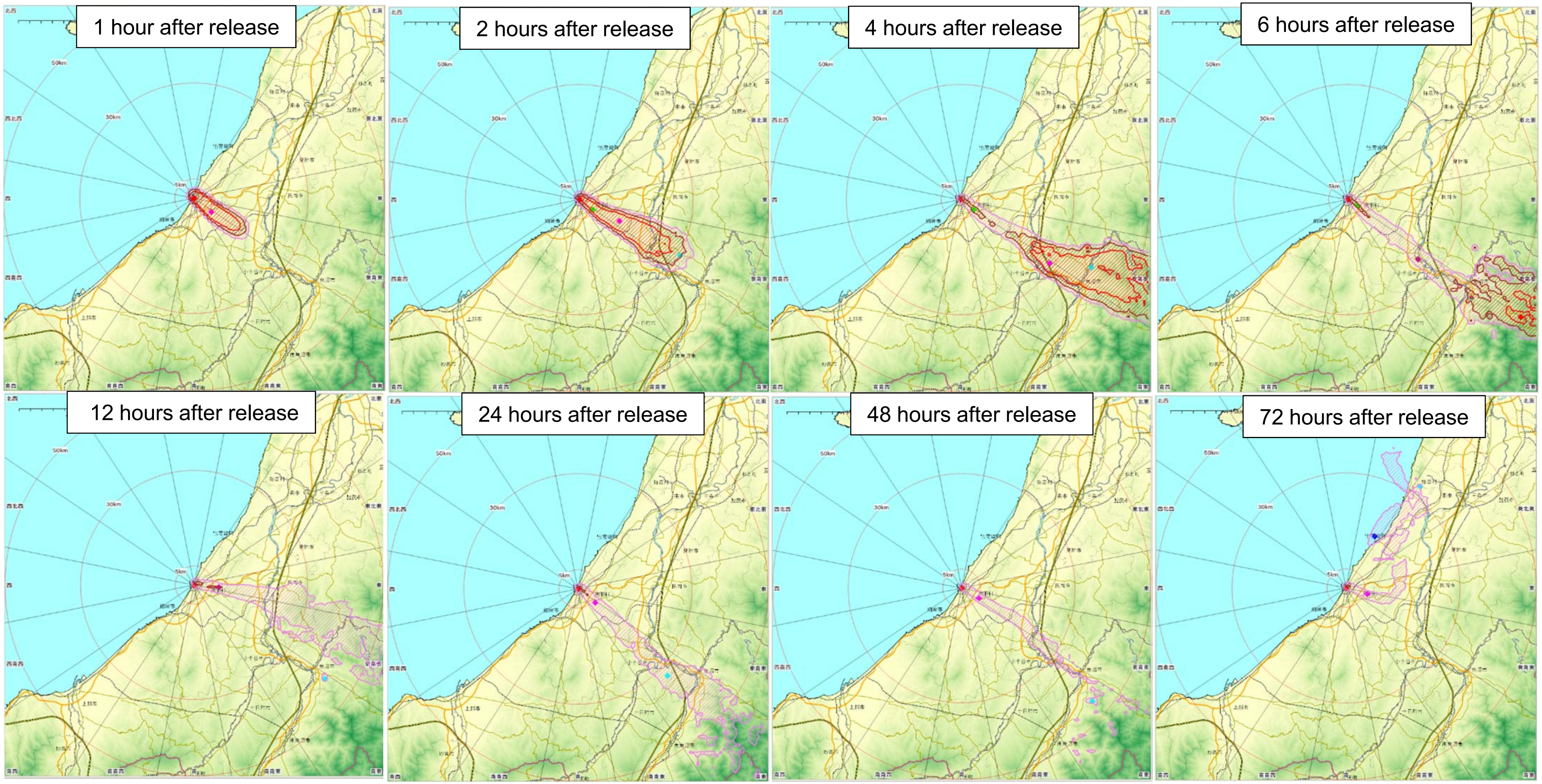
<For Comparison> with filter vent
① Venting after 25 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 25 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium

Isogram: Air Absorbed Dose Rate

- 5.0E+02 ～ μGy/h
- 2.0E+01 ～ 5.0E+02 μGy/h
- 5.0E-01 ～ 2.0E+01 μGy/h



3-2. Examples of Assessed Air Dose Rate

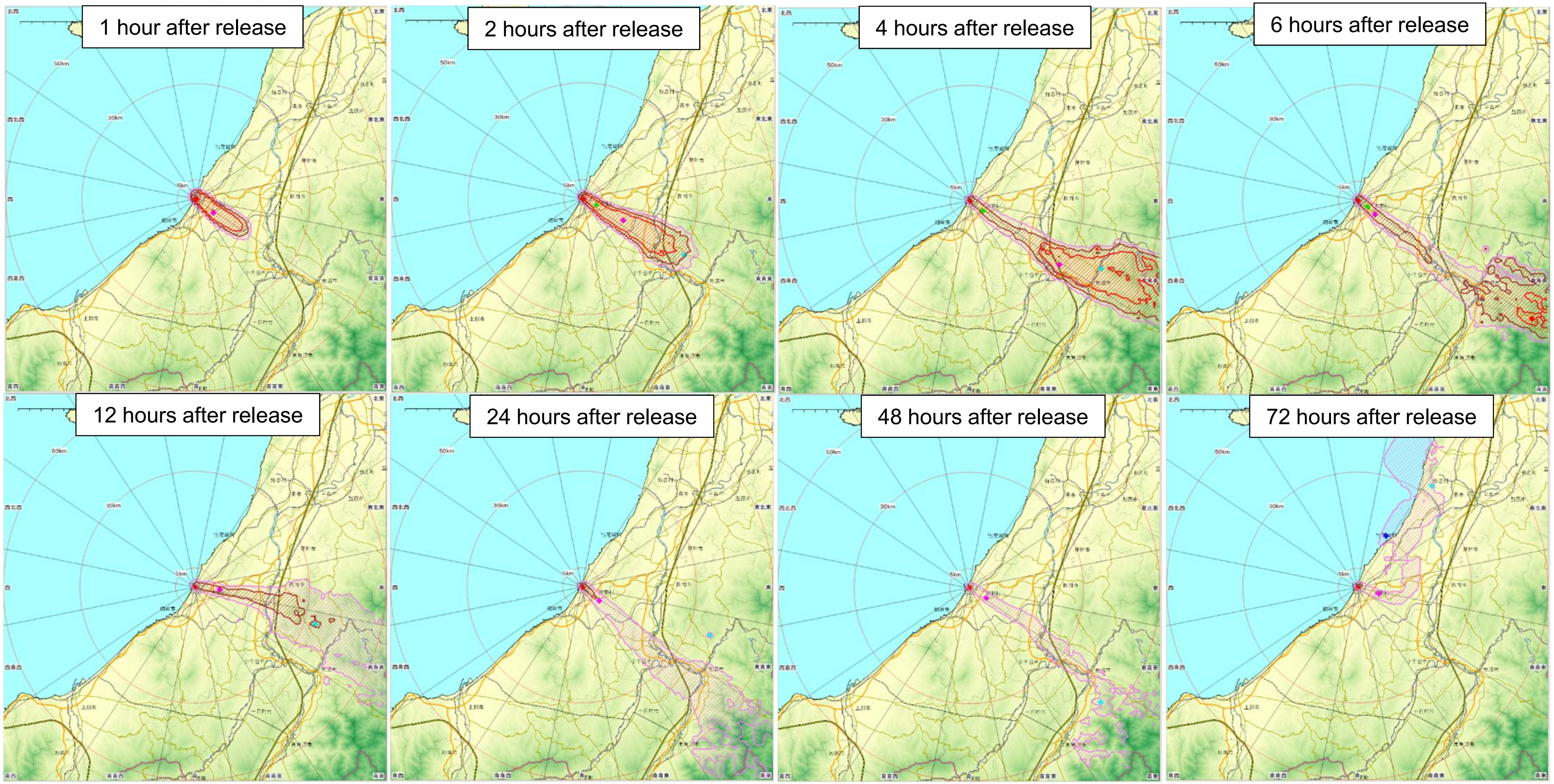
<For Comparison> with filter vent
② Venting after 18 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Isogram: Air Absorbed Dose Rate

- 5.0E+02 ～ μGy/h
- 2.0E+01 ～ 5.0E+02 μGy/h
- 5.0E-01 ～ 2.0E+01 μGy/h

Case	Venting after 18 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium



3-2. Examples of Assessed Air Dose Rate

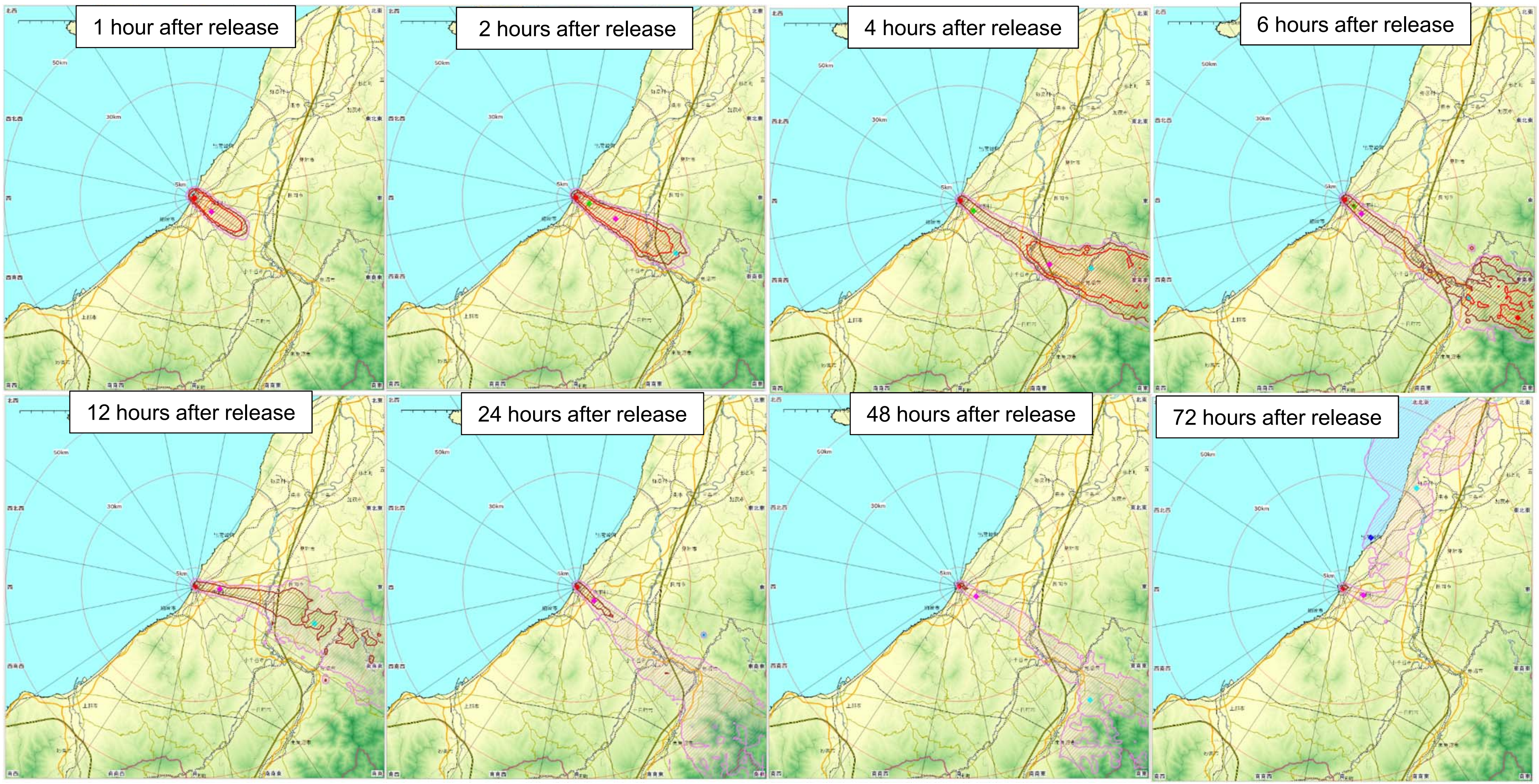
<For Comparison> **with filter vent**
③ Venting after 6 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 6 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium

Isogram: Air Absorbed Dose Rate

- 5.0E+02 ～ μGy/h
- 2.0E+01 ～ 5.0E+02 μGy/h
- 5.0E-01 ～ 2.0E+01 μGy/h



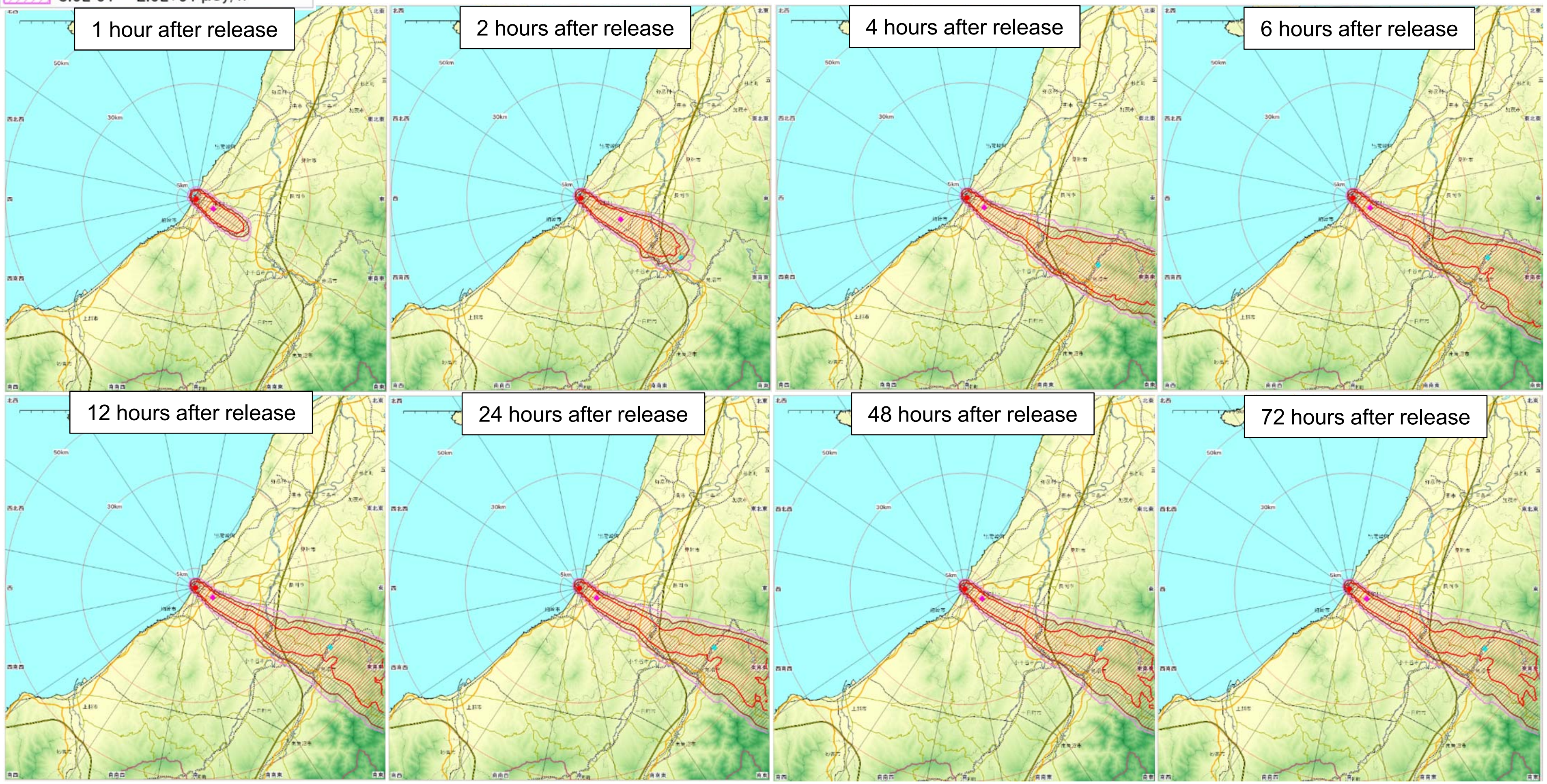
<For Comparison> **without filter vent**
④ Reference case

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Reference case (PCV destroyed in 8 hours, without filter vent）
Nuclide	Noble gas, Iodine, Cesium

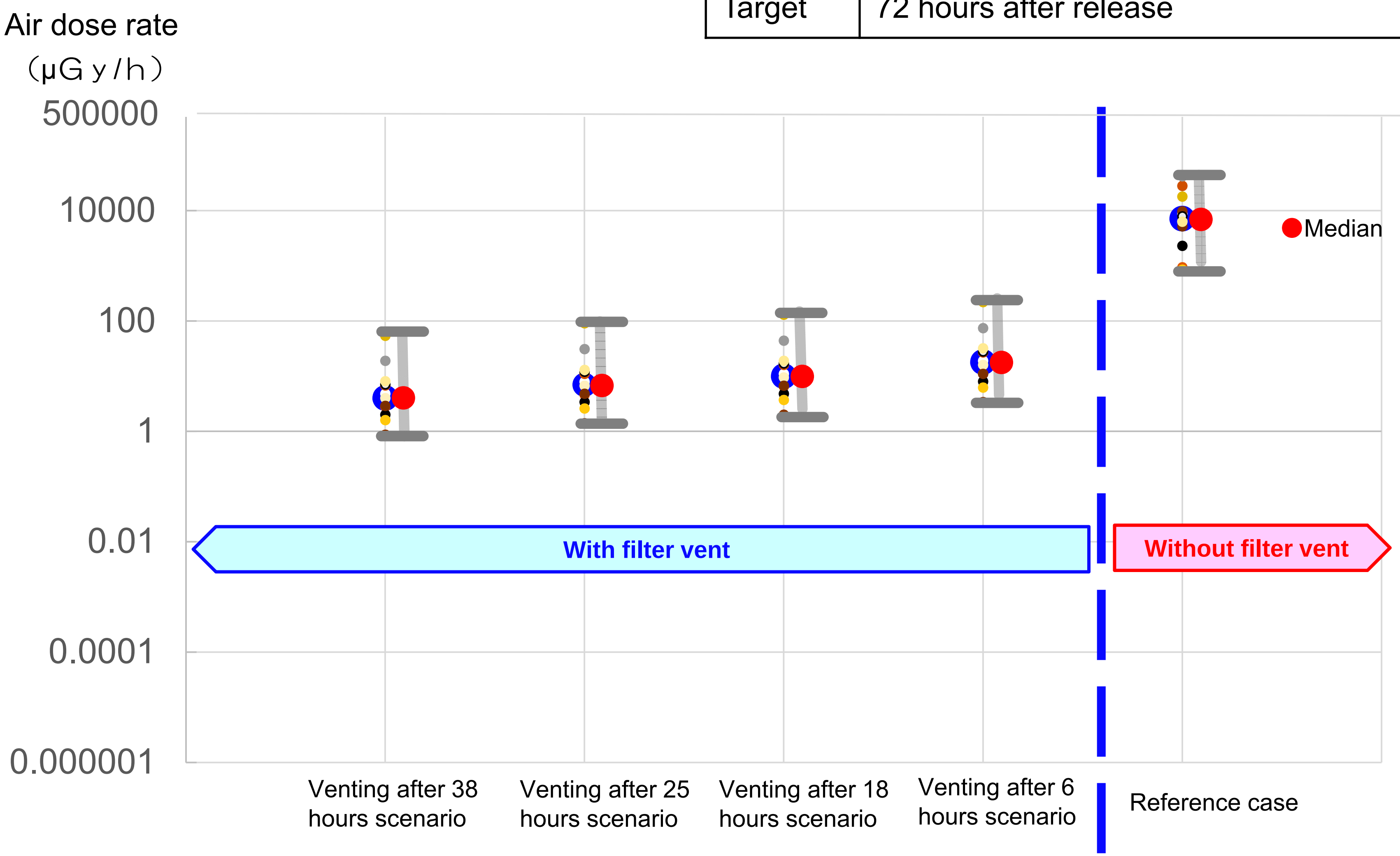
Isogram: Air Absorbed Dose Rate

- 5.0E+02 ～ μGy/h
- 2.0E+01 ～ 5.0E+02 μGy/h
- 5.0E-01 ～ 2.0E+01 μGy/h



3-3. Assessment Results of Air Dose Rate (Variability of maximum values within PAZZ)

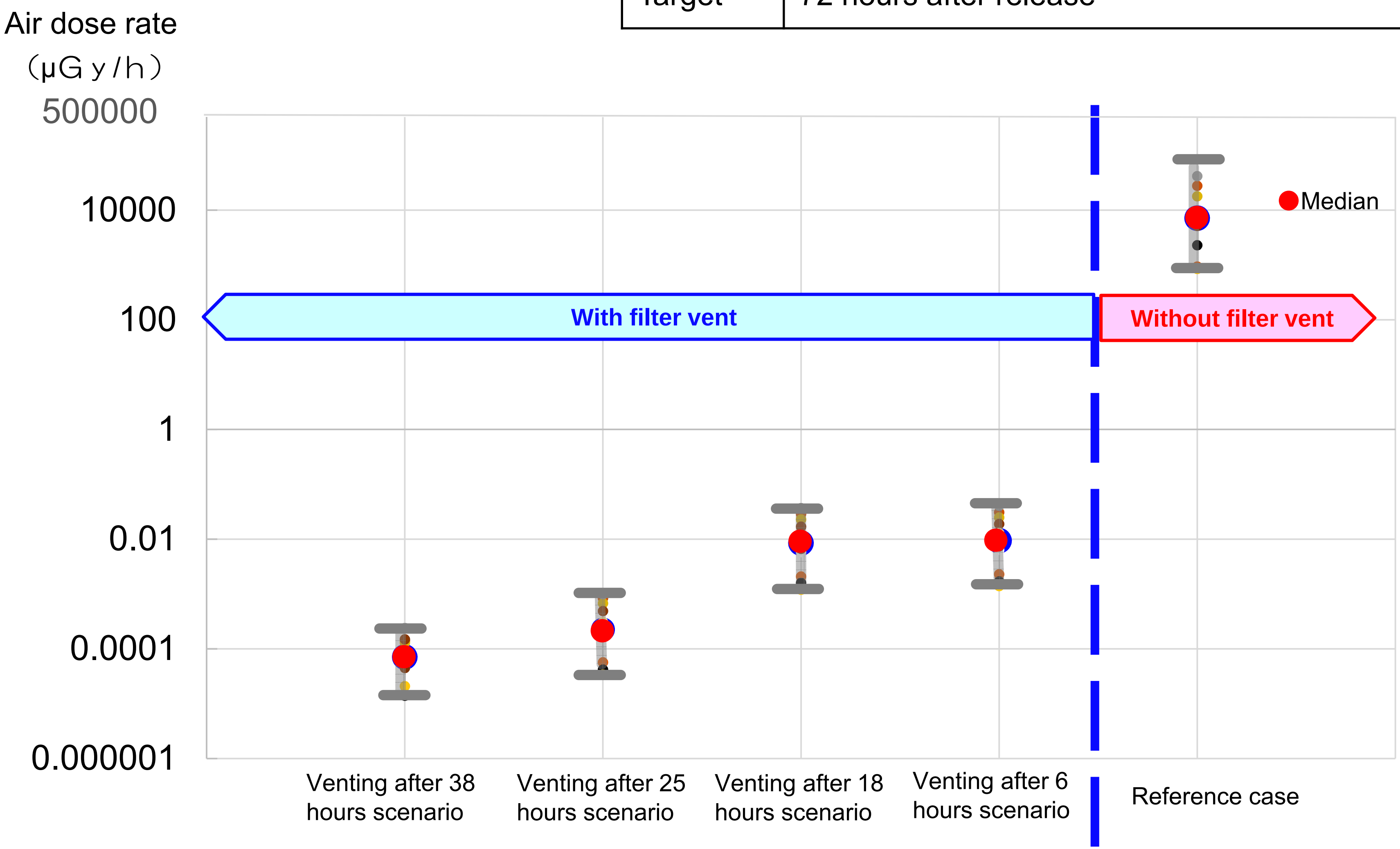
Nuclide	Noble gas, Iodine, Cesium
Target	72 hours after release



※The air dose rate figure of each accident scenario in the graph above is the maximum figure assessed in 12 weather patterns which are mentioned on Sheet 4.

3-3. Assessment Results of Air Dose Rate from Radiation on the Ground Surface (Variability of maximum values within PAZZ)

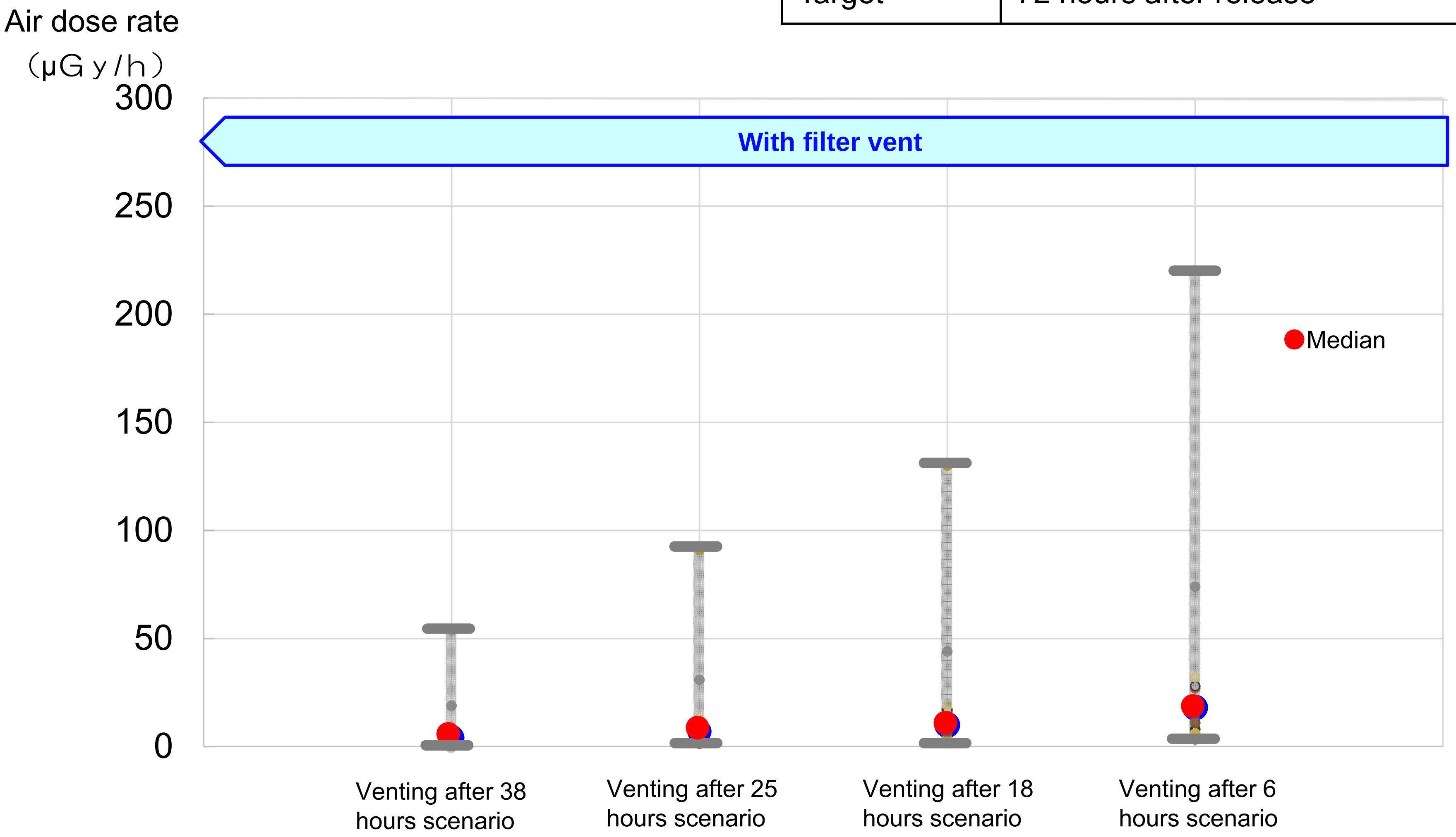
Nuclide	Iodine, Cesium (Surface accumulation)
Target	72 hours after release



※The air dose rate figure of each accident scenario in the graph above is the maximum figure assessed in 12 weather patterns which are mentioned on Sheet 4.

3-3. Assessment Results of Air Dose Rate (Variability of maximum values within PAZZ)

Nuclide	Noble gas
Target	72 hours after release



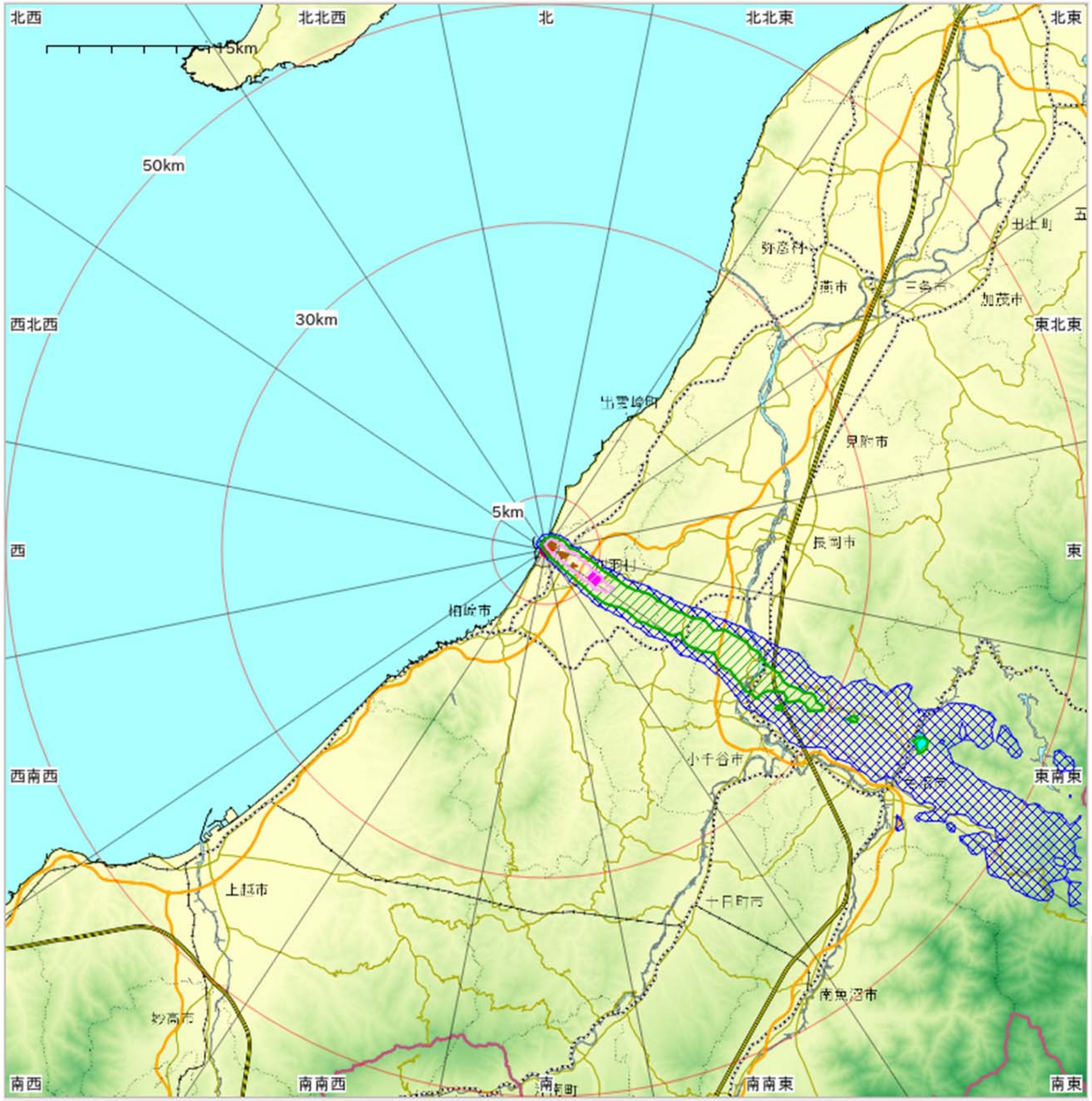
※The air dose rate figure of each accident scenario in the graph above is the maximum figure assessed in 12 weather patterns which are mentioned on Sheet 4.

3-4. Examples of Assessed External Exposure Dose (Effective Dose)

[Base case] with filter vent
Venting after 38 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 38 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No



Isogram: External Exposure Effective Dose

- 1.0E+02 ～ mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv
- 5.0E+00 ～ 2.0E+01 mSv
- 1.0E+00 ～ 5.0E+00 mSv

3-4. Examples of Assessed External Exposure Dose (Effective Dose)

<For Comparison> with filter vent
① Venting after 25 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 25 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

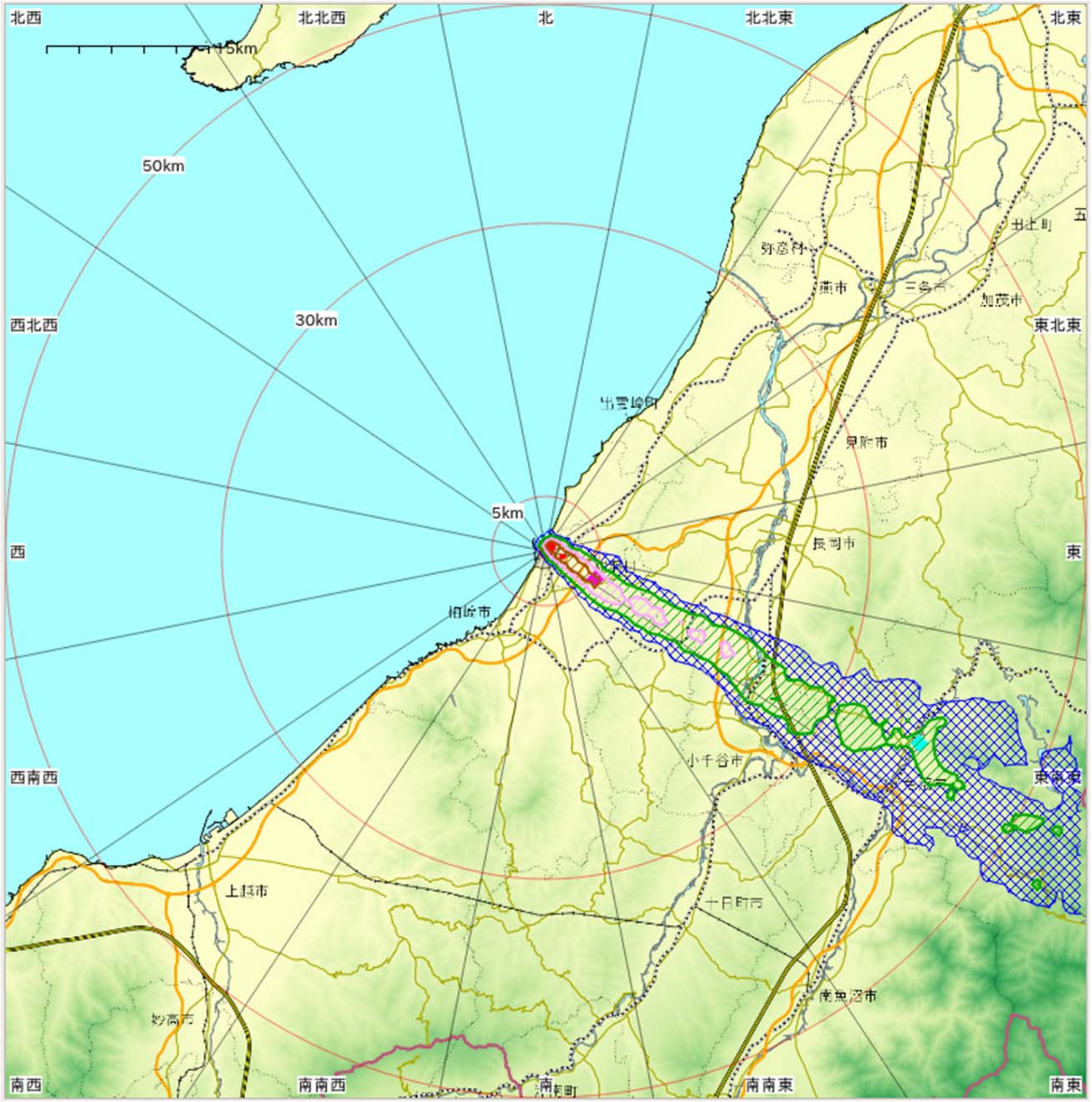
Isogram: External Exposure Effective Dose

- 1.0E+02 ～ mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv
- 5.0E+00 ～ 2.0E+01 mSv
- 1.0E+00 ～ 5.0E+00 mSv

3-4. Examples of Assessed External Exposure Dose (Effective Dose)

＜For Comparison＞with filter vent
② Venting after 18 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]



Case	Venting after 18 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: External Exposure Effective Dose

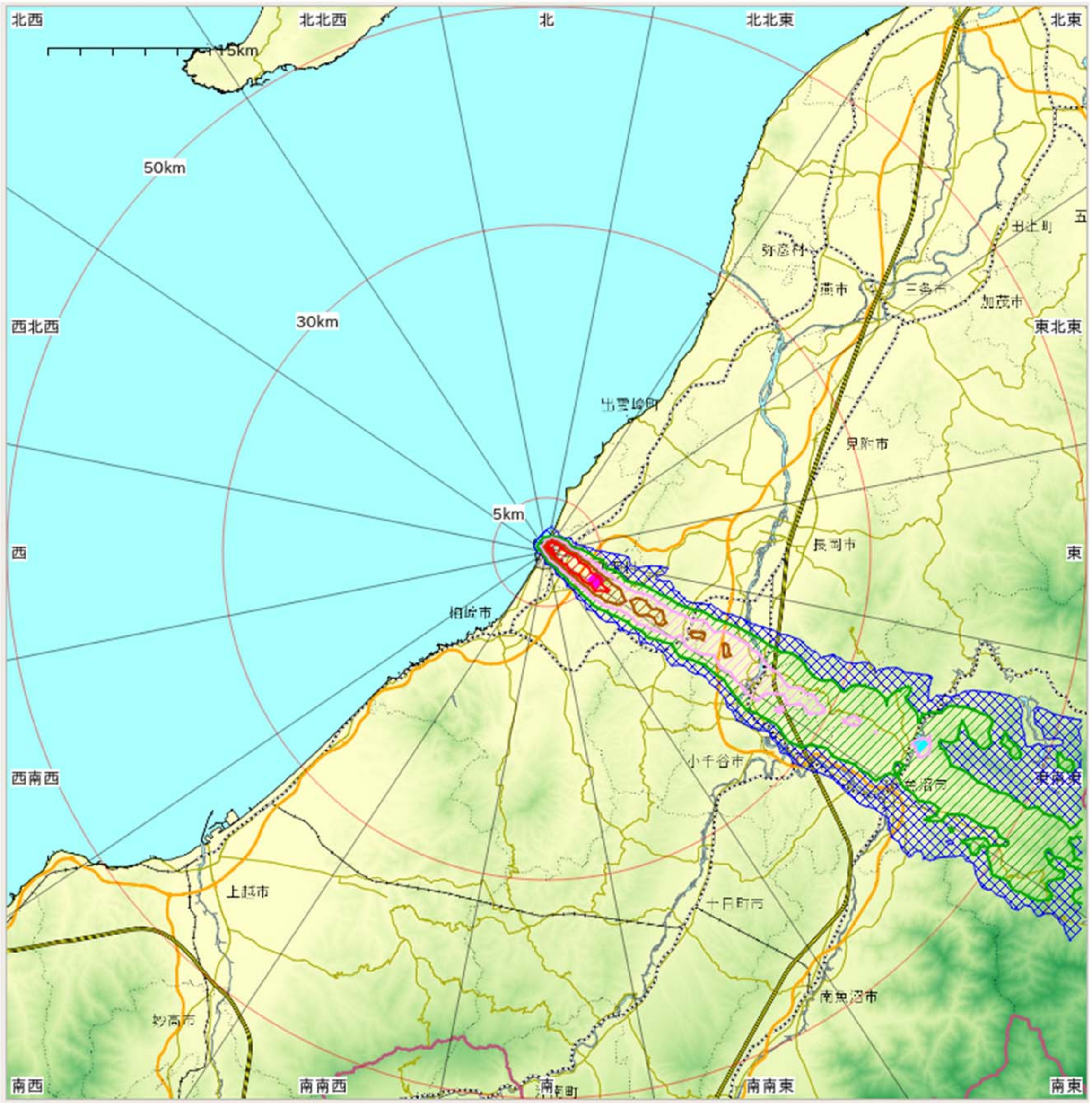
- 1.0E+02 ～ mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv
- 5.0E+00 ～ 2.0E+01 mSv
- 1.0E+00 ～ 5.0E+00 mSv

3-4. Examples of Assessed External Exposure Dose (Effective Dose)

＜For Comparison＞**with filter vent**
③ Venting after 6 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 6 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

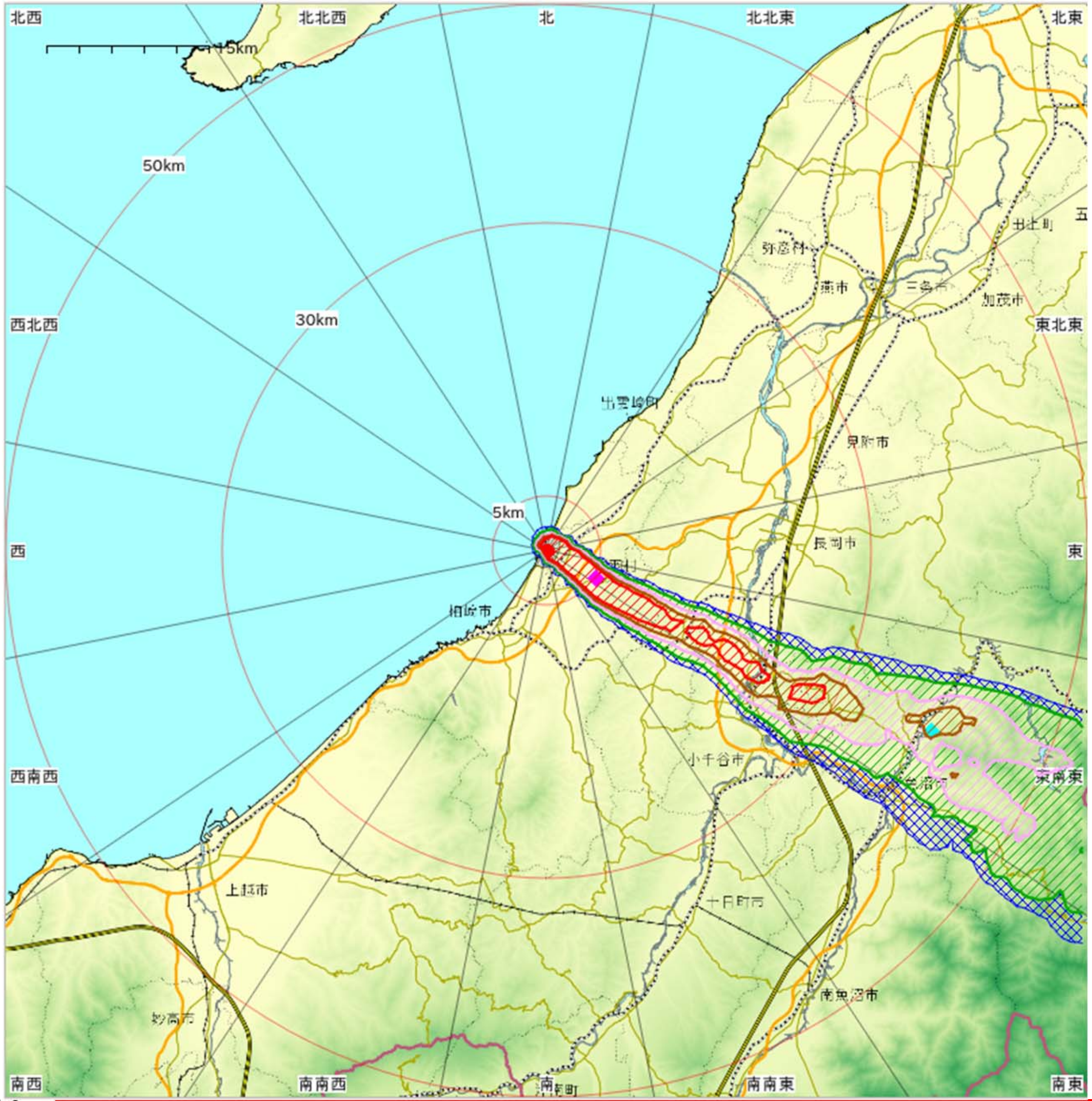


Isogram: External Exposure Effective Dose

- 1.0E+02 ～ mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv
- 5.0E+00 ～ 2.0E+01 mSv
- 1.0E+00 ～ 5.0E+00 mSv

＜For Comparison＞ Without **filter vent**
④ **Reference Case**

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]



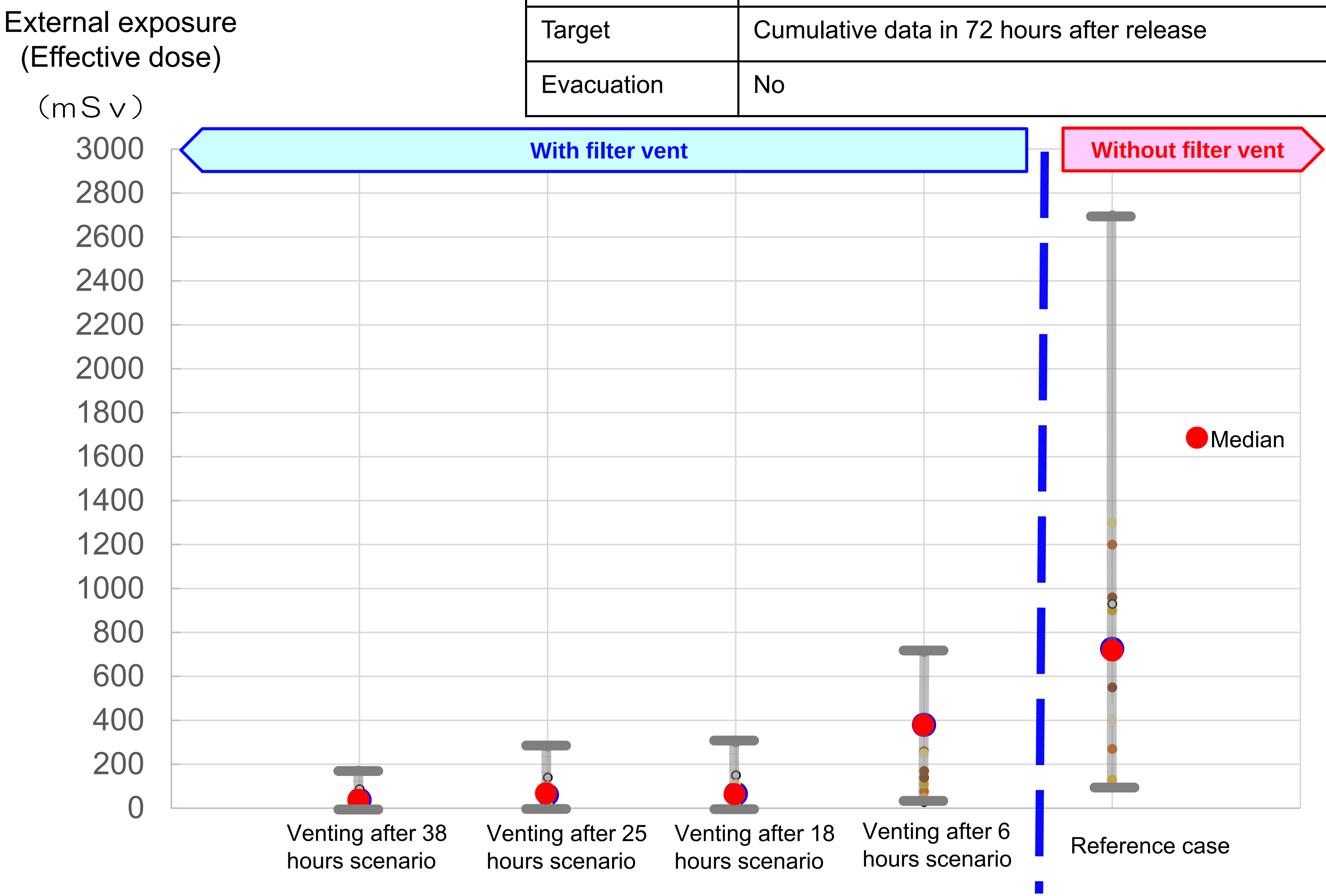
Case	Reference case (PCV destroyed in 8 hours, without filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: External Exposure Effective Dose

- 1.0E+02 ～ mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv
- 5.0E+00 ～ 2.0E+01 mSv
- 1.0E+00 ～ 5.0E+00 mSv

3-5. Assessment Results of External Exposure (Effective Dose) (Variability of maximum values within PAZZ)

Nuclide	Noble gas, Iodine, Cesium
Target	Cumulative data in 72 hours after release
Evacuation	No



※The external exposure effective dose figure of each accident scenario in the graph above is the maximum figure assessed in 12 weather patterns which are mentioned on Sheet 4.

3-6. Examples of Assessed Thyroid Equivalent Dose Due to Exposure to Iodine

[Base case] with filter vent
Venting after 38 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 38 hours scenario (with filter vent)
Nuclide	Iodine
Evacuation	No

Isogram: Thyroid Equivalent Dose

- 5.0E+02 ～ mSv
- 1.0E+02 ～ 5.0E+02 mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv

3-6. Examples of Assessed Thyroid Equivalent Dose Due to Exposure to Iodine

<For Comparison> with filter vent
① Venting after 25 hours scenario

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 25 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: Thyroid Equivalent Dose

- 5.0E+02 ～ mSv
- 1.0E+02 ～ 5.0E+02 mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 18 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: Thyroid Equivalent Dose

- 5.0E+02 ～ mSv
- 1.0E+02 ～ 5.0E+02 mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv

<For Comparison> **with filter vent**
③ Venting after 6 hours scenario

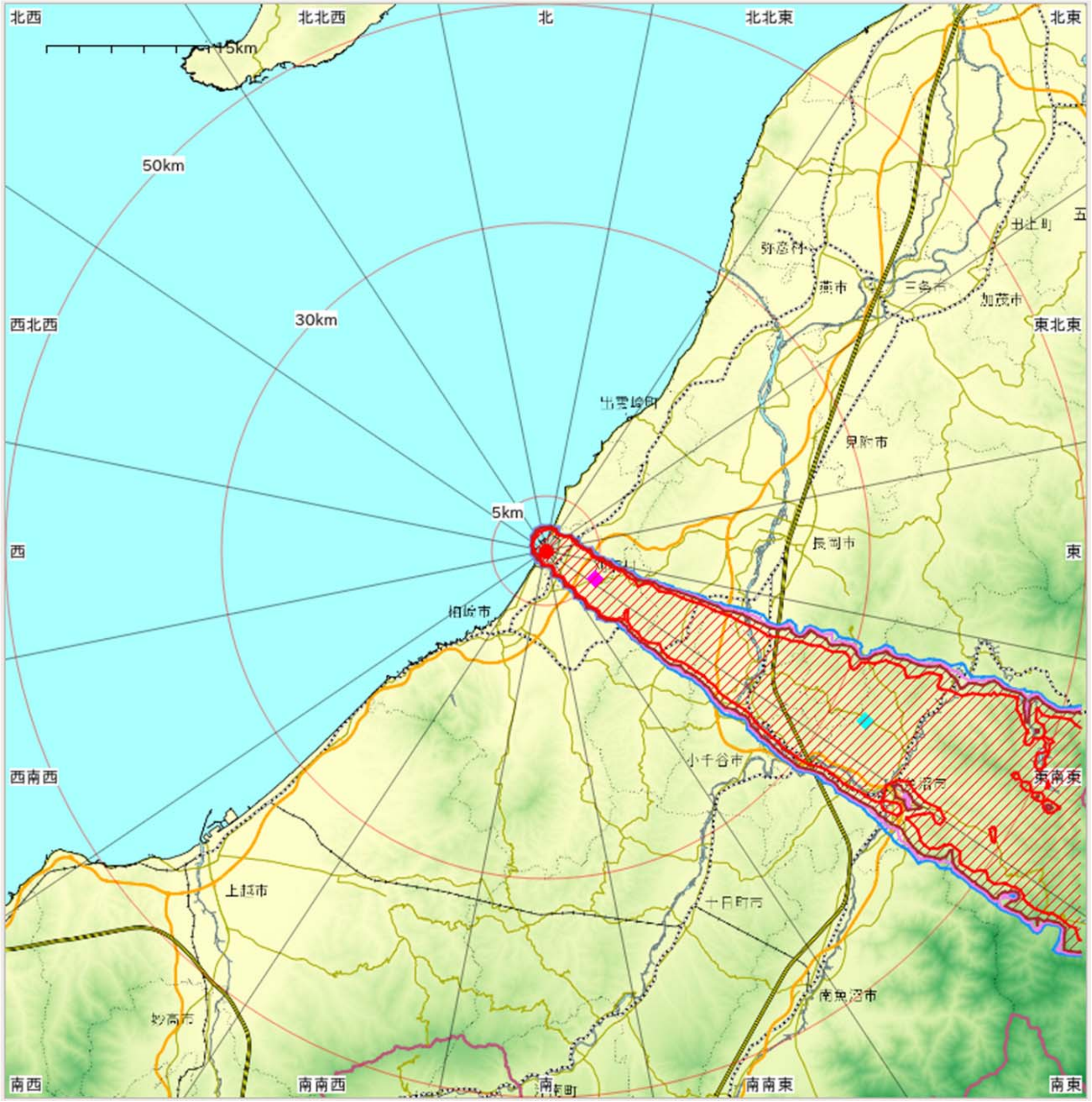
Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]

Case	Venting after 6 hours scenario (with filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: Thyroid Equivalent Dose

- 5.0E+02 ～ mSv
- 1.0E+02 ～ 5.0E+02 mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv

Assessment Result [Northwest (wind direction), Medium (wind speed), Rainfall]



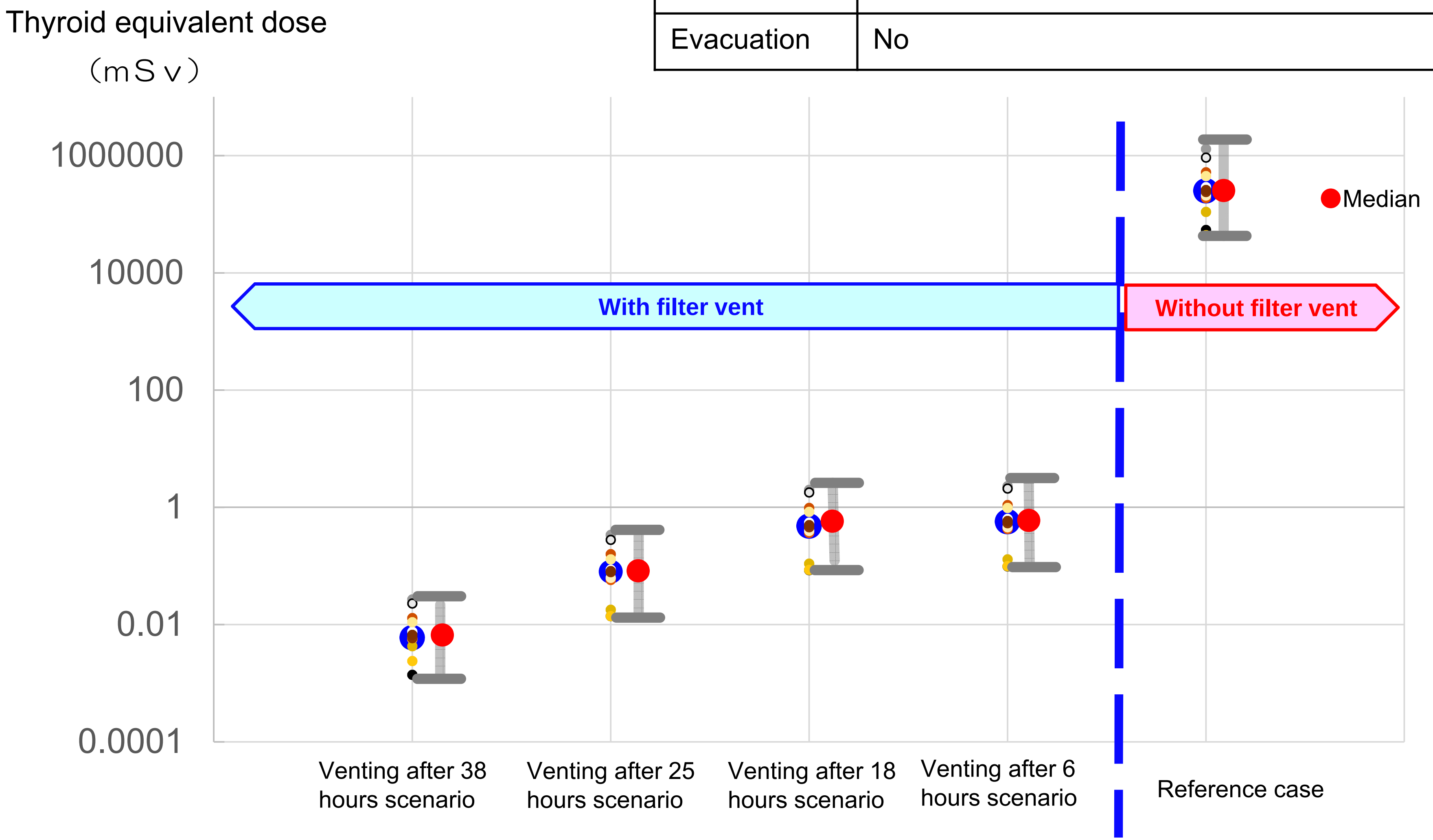
Case	Reference case (PCV destroyed in 8 hours, without filter vent)
Nuclide	Noble gas, Iodine, Cesium
Evacuation	No

Isogram: Thyroid Equivalent Dose

- 5.0E+02 ～ mSv
- 1.0E+02 ～ 5.0E+02 mSv
- 5.0E+01 ～ 1.0E+02 mSv
- 2.0E+01 ～ 5.0E+01 mSv

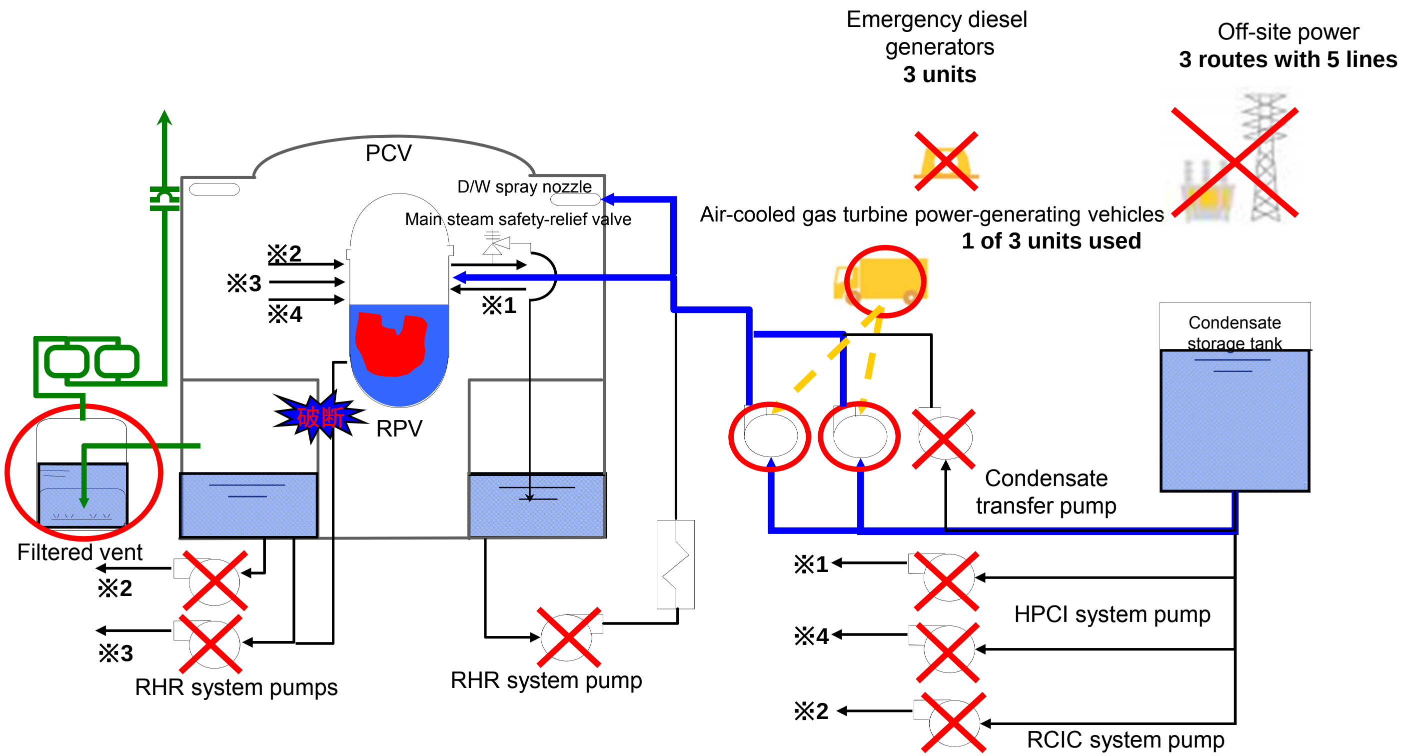
3-5. Assessment Results of Thyroid Equivalent Dose Due to Exposure to Iodine (Variability of maximum values within PAZZ)

Nuclide	Iodine
Target	Cumulative data in 72 hours after release
Evacuation	No



※The thyroid equivalent dose figure of each accident scenario in the graph above is the maximum figure assessed in 12 weather patterns which are mentioned on Sheet 4.

Reference



【Preconditions for base case & case ①: Following states are assumed to continue unconditionally】

➢A incident occurs in which a large quantity of water inside the reactor is lost
➢All facilities for injecting cooling water into the reactor are unusable during the accident (however, some facilities inside the building are able to be used to inject cooling water into the reactor)

②Venting after 25 hours

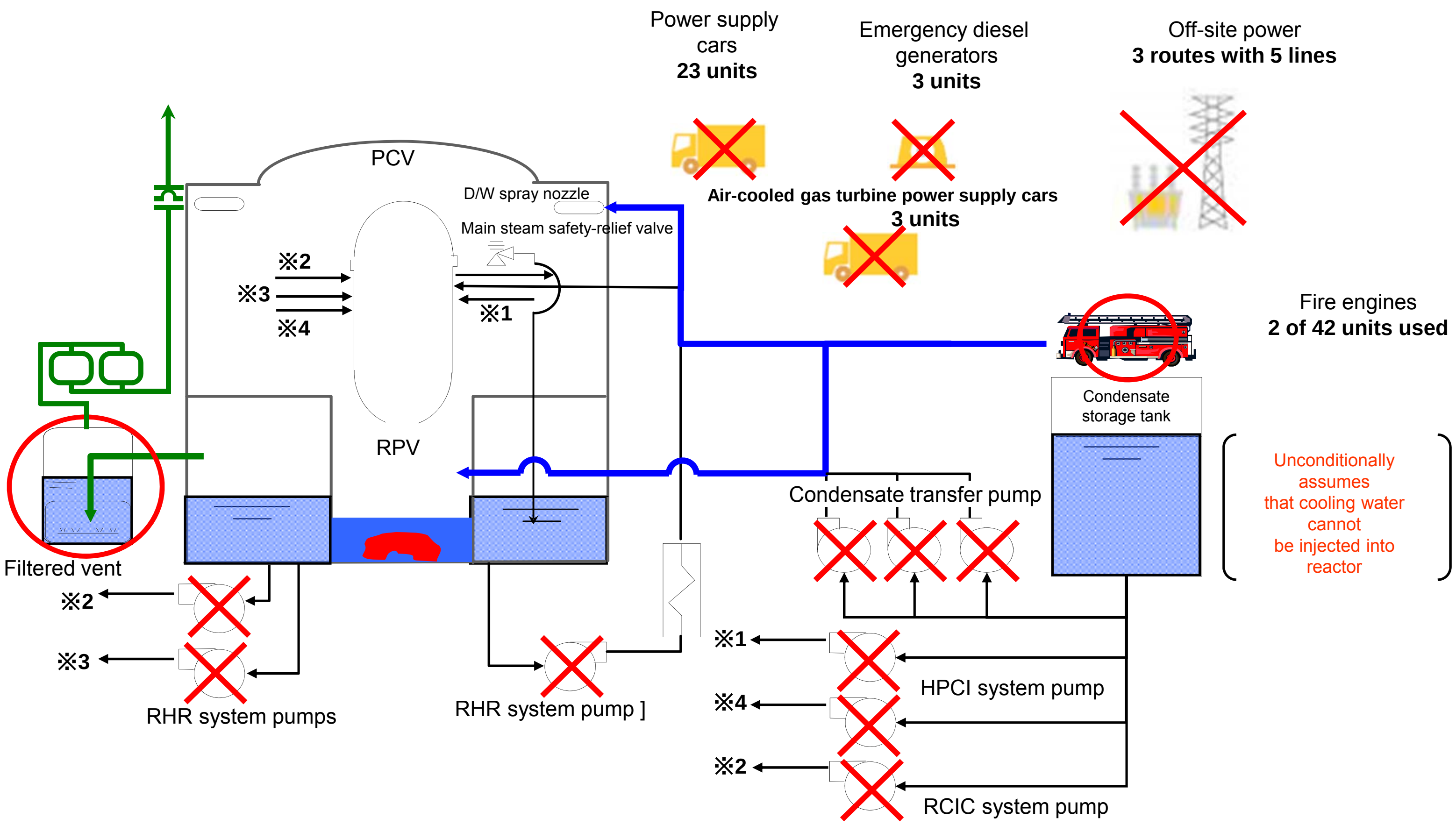
(Previous scenario at time of establishment permit application)

Operational improvements and enhanced skills due to training
➢Start of receiving power from gas-turbine generator lowered from 120 minutes ⇒ 70 minutes
➢Quantity of water supplied from reservoir to condensate storage tank increased from 90m^3/h ⇒ 130m^3/h etc.

①Venting after 38 hours

(Regulatory licensing review scenario)

② Venting After 18 Hours Scenario

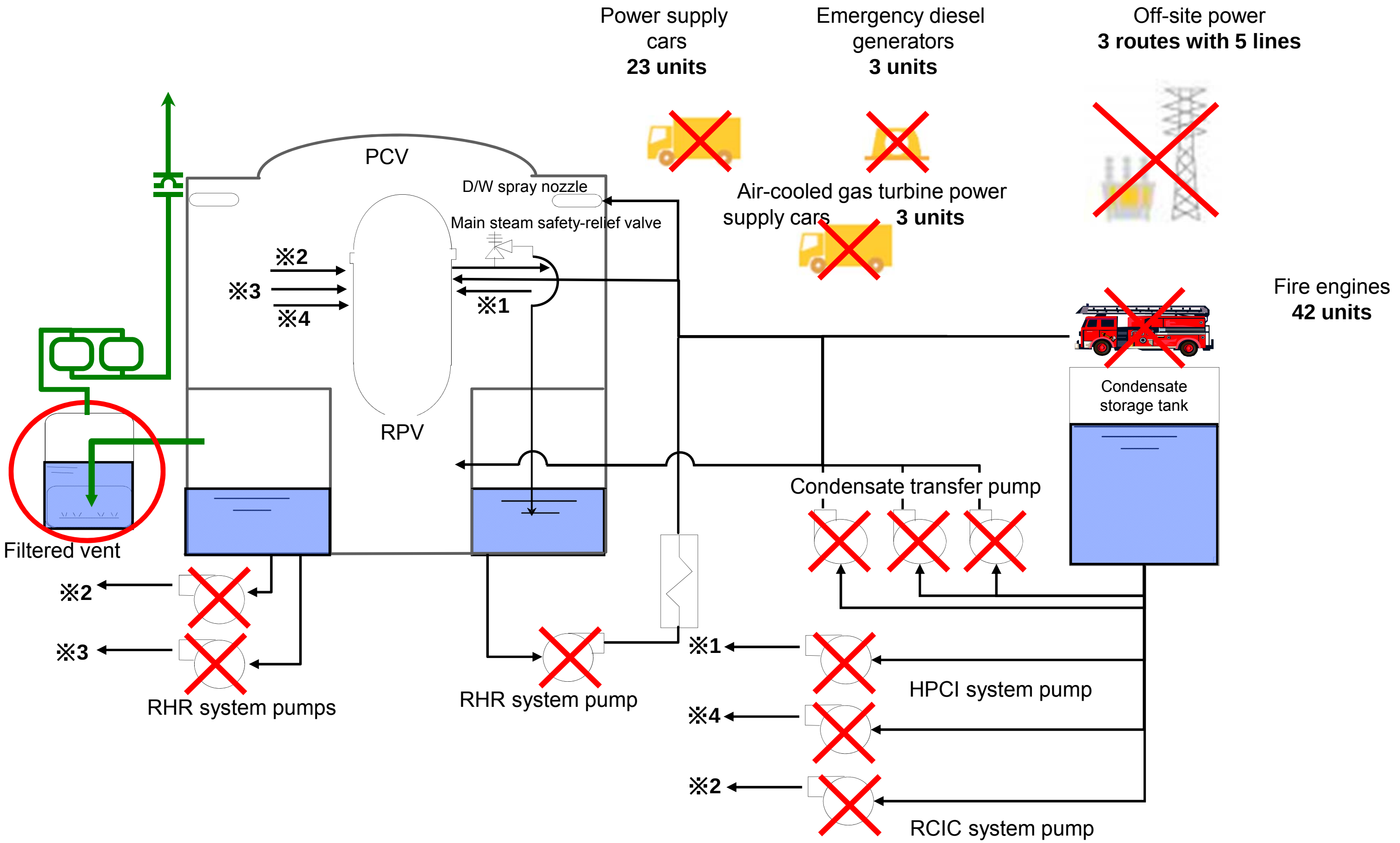


【Preconditions for case ②: Following states are assumed to continue unconditionally】

- ➢All facilities inside the building for injecting cooling water into the reactor are unusable
- ➢Fire engines unable to inject cooling water into reactor (cooling water can be injected only into the PCV)

③Venting after 18 hours

③ Venting After 6 Hours Case: No Scenario

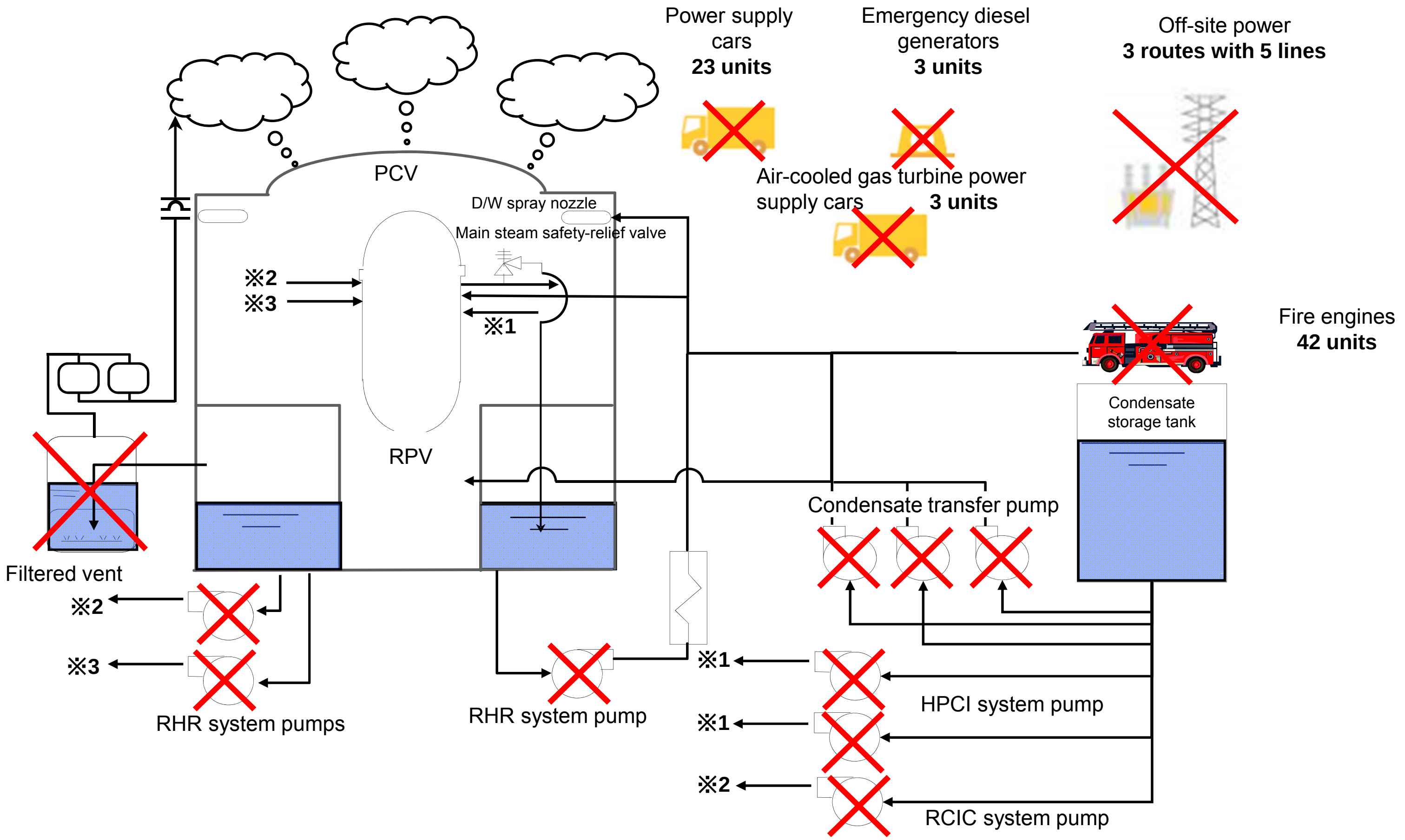


【Preconditions for case ③: Following states are assumed to continue **unconditionally**】

- Soundness of PCV forcibly maintained
- Only FV usable

→ **④Venting after 6 hours**

④ Reference Case



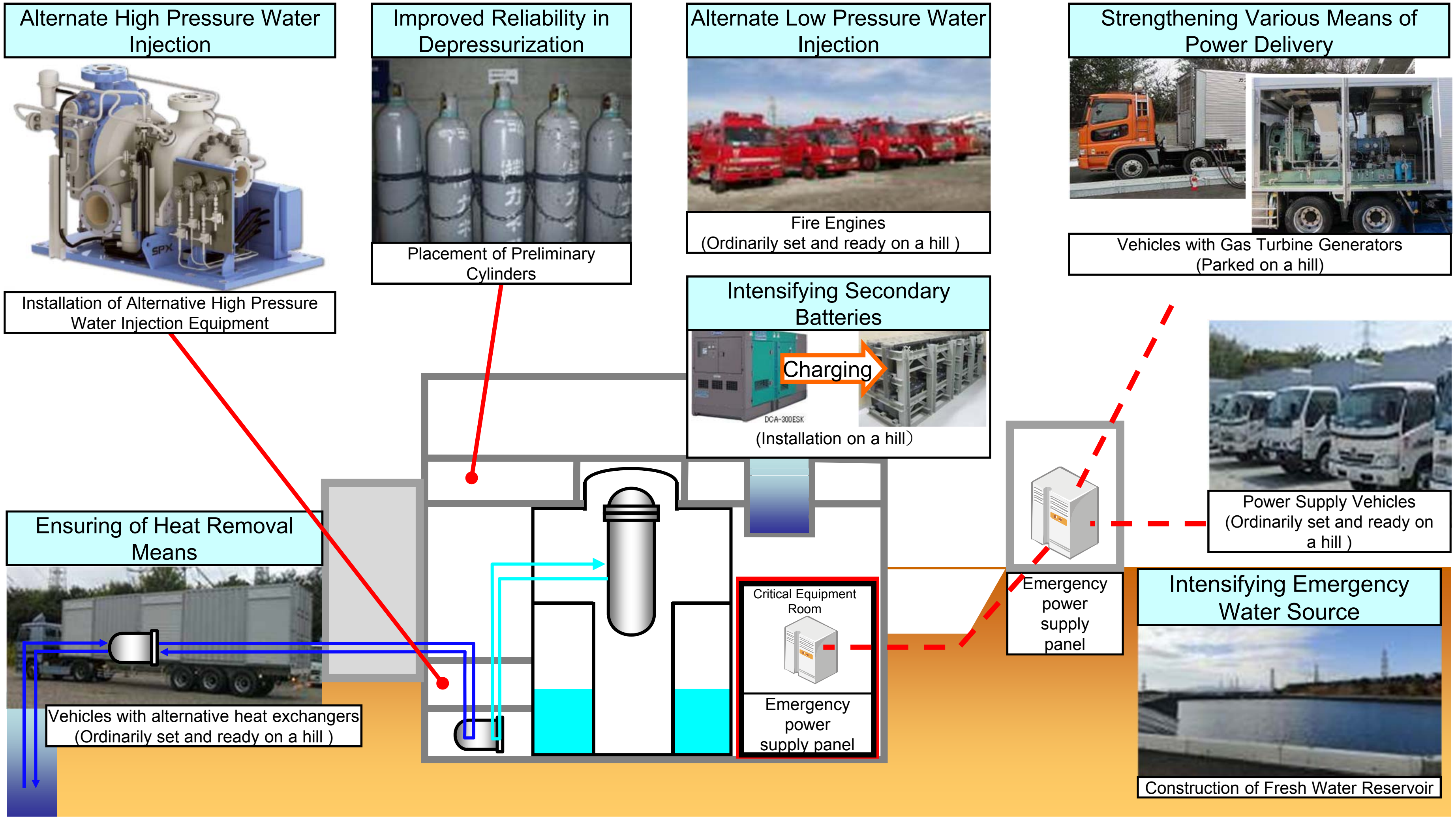
【Preconditions for case ④: Following states are assumed to continue unconditionally】

- All facilities inside the power station are unusable

⑤PCV damage after 8 hours

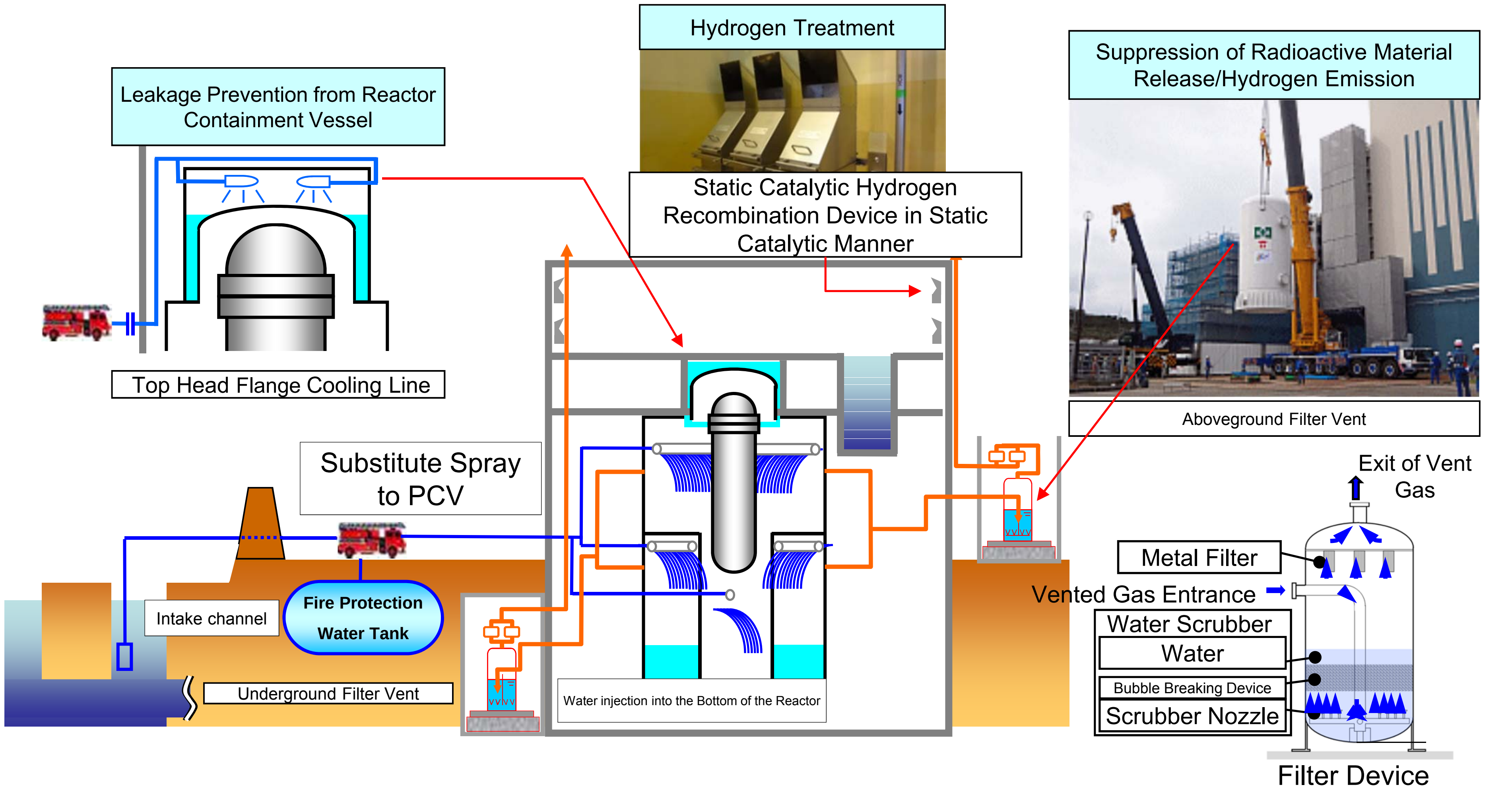
Preparation for severe accidents (1/2)

■ **With various measures, nuclear reactor cooling function is being enhanced.**



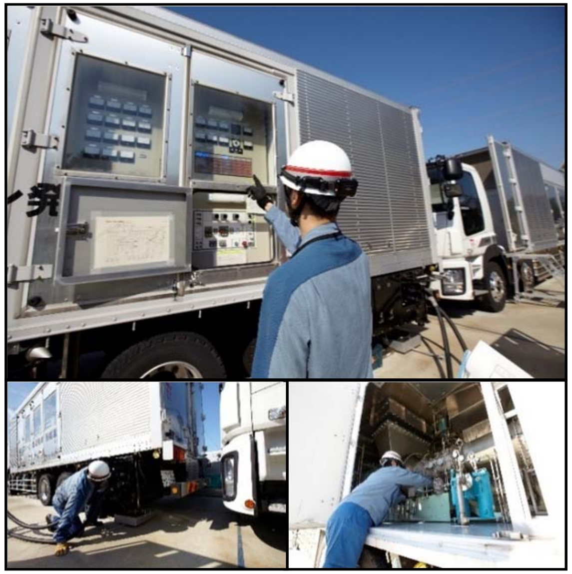
Preparation for severe accident (2/2)

- **In case that the core is damaged, means for moderating thermal effect have been strengthened.**
- **Filtered venting system is one of the facilities for the means to be set up in order to eliminate more than 99.9% of particulate radioactive materials.（the primary cause of ground pollution at Fukushima is Cesium -137）**



■Enhancing competence by drills and improvements in administration enable to extend the time to containment venting.

- Injecting water into a reactor as early as possible by being able to use gas turbine generators smoothly
- Preventing dry up of cooling water for containment vessel by enhancing water supply from a reservoir



Drill to start turbine generators

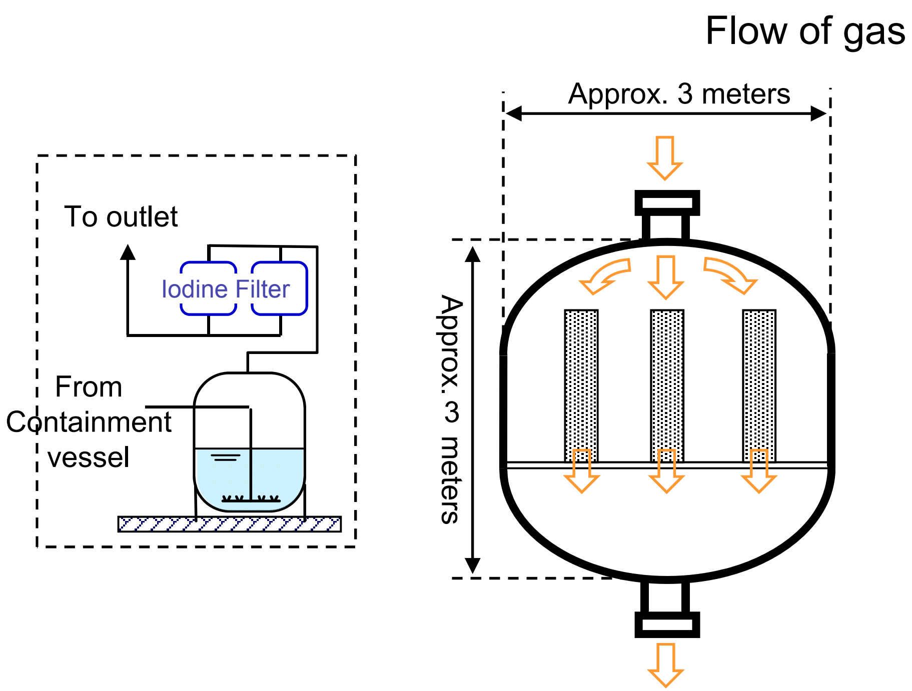
■ Stretching Containment Vessel Venting: about 25 hours → about 38 hours
(① case) (base case)

⇒By doing this, noble gas is attenuated further and the emission amount will be reduced.

■ **Installing alkali control and iodine filters reduces iodine at the time of conducting containment venting.**

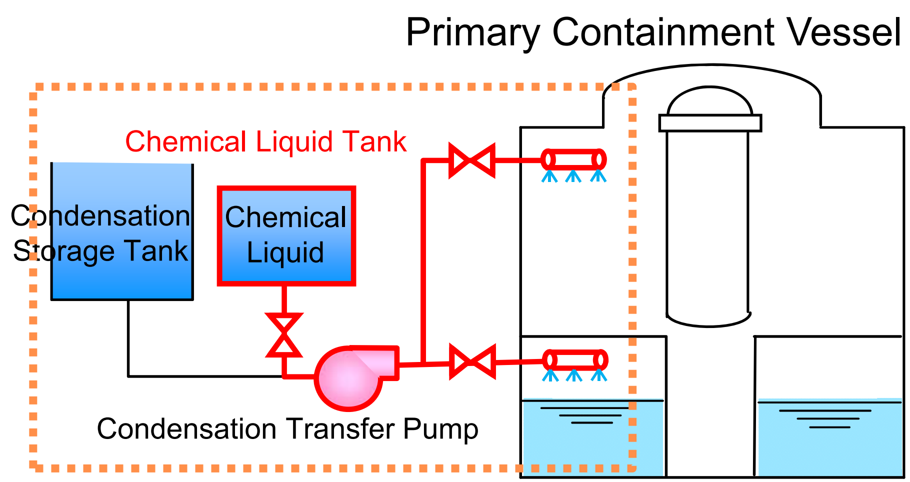
Iodine filter

More than 98% of gaseous Iodine (organic Iodine) can be removed after going through filter device.



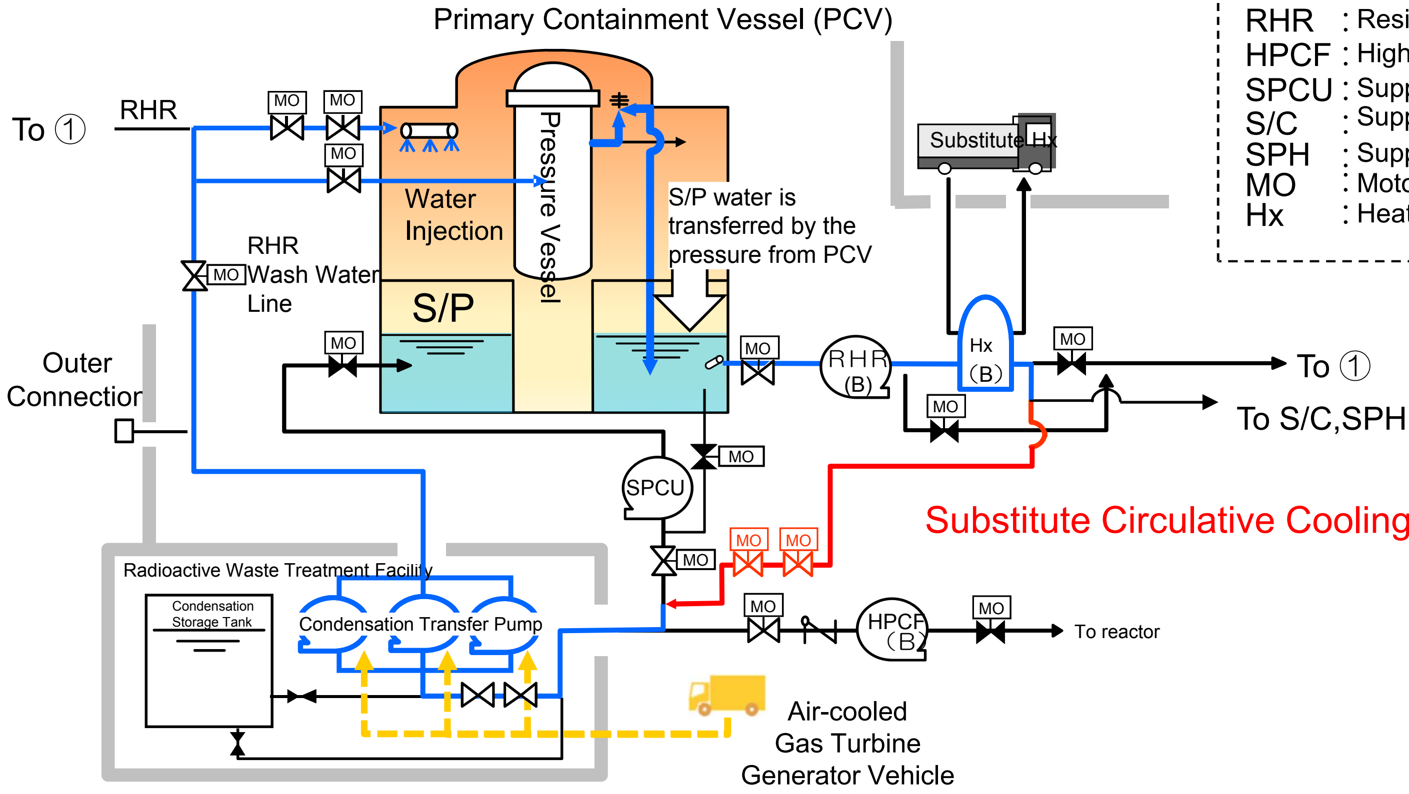
pH control inside containment vessel

The amount of Iodine emission can be reduced by making water inside containment vessel alkaline and preventing the generation of gaseous Iodine.



Reduction of Radioactive Materials Emission by Avoiding Containment Vessel Venting (Substitute circulative cooling)

■Venting containment vessel can be avoided by controlling pressure increase inside containment vessel and installing a substitute circulative cooling line to remove heat while circulating suppression pool water.



Abbreviation
RHR : Residual Heat Removal System
HPCF : High Pressure Core Flooder System
SPCU : Suppression Pool Water Clean-up System
S/C : Suppression Chamber
SPH : Suppression Pool Water Draining System
MO : Motor Operated Valve
Hx : Heat Exchanger