Status of Radiation protection efforts in Fukushima Daiichi NPS

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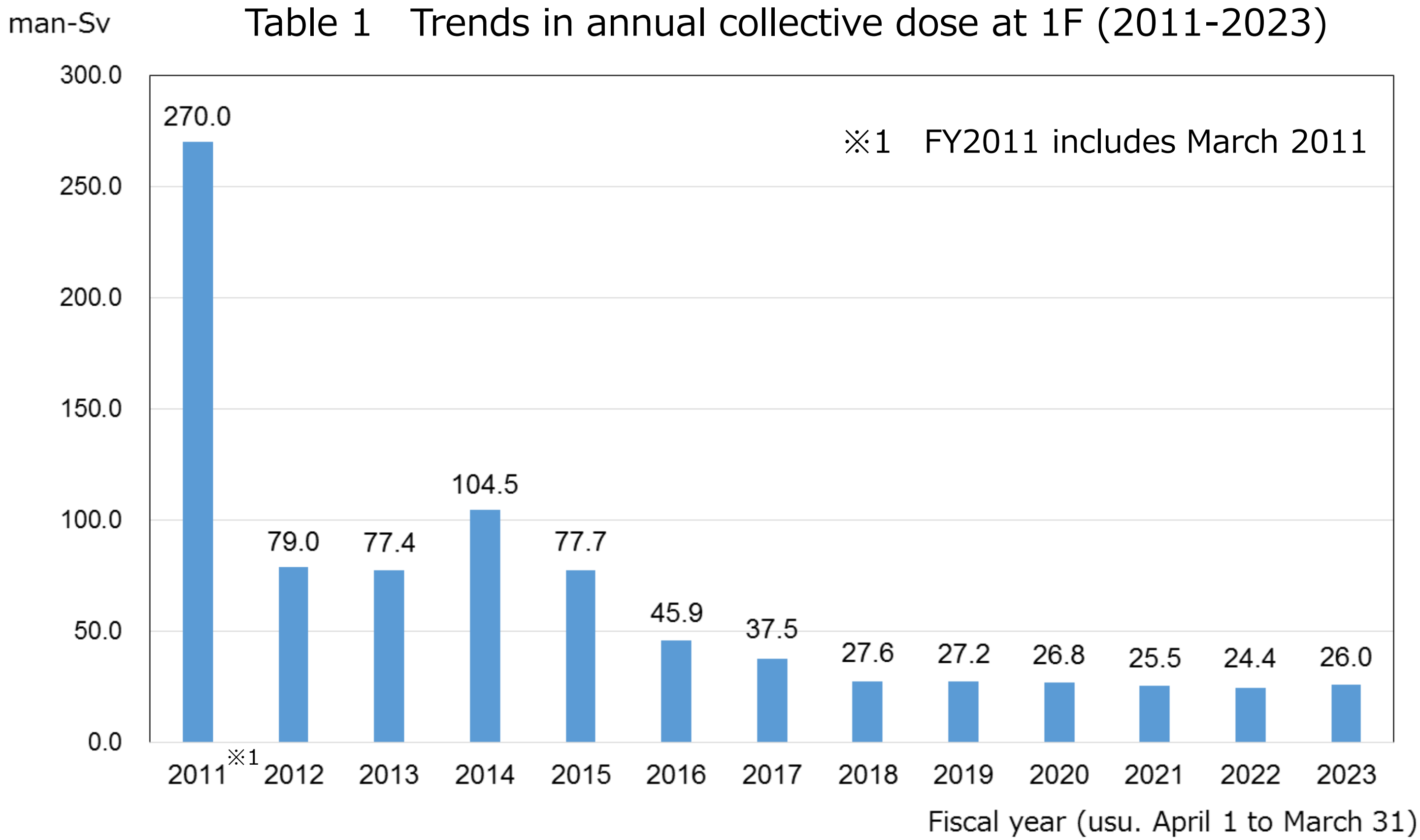
Exposure of workers at Fukushima Daiichi NPS（1F）

- External exposure doses (total effective doses) since the Fukushima Daiichi nuclear accident have been decreasing year by year due to efforts to improve working environments through decontamination and shielding. However, since 2018, they have generally remained stable.
- We expect this trend to continue for the foreseeable future, as we plan to continue working in high-dose environments, including fuel debris retrieval operations.

Table 1　Trends in annual collective dose at 1F (2011-2023)



Working environment at 1F NPS [Dose equivalent rate] (Entire premises)

- In the mid-2010s, most of the areas around Units No.1-4 were over 100 μSv/h (orange : , pink : and red :), and there were many other areas with several tens of μSv/h (light blue : and green :).
- Currently, due to dose reduction measures such as retrieval of high-dose debris, topsoil contaminated by fallout, and facing (spraying mortar and asphalt pavement) of the ground surface, the area around Units No.1-4 is below 100 μSv/h (yellow : and green :), and majority of the entire premises area is now below 5 μSv/h (blue :).

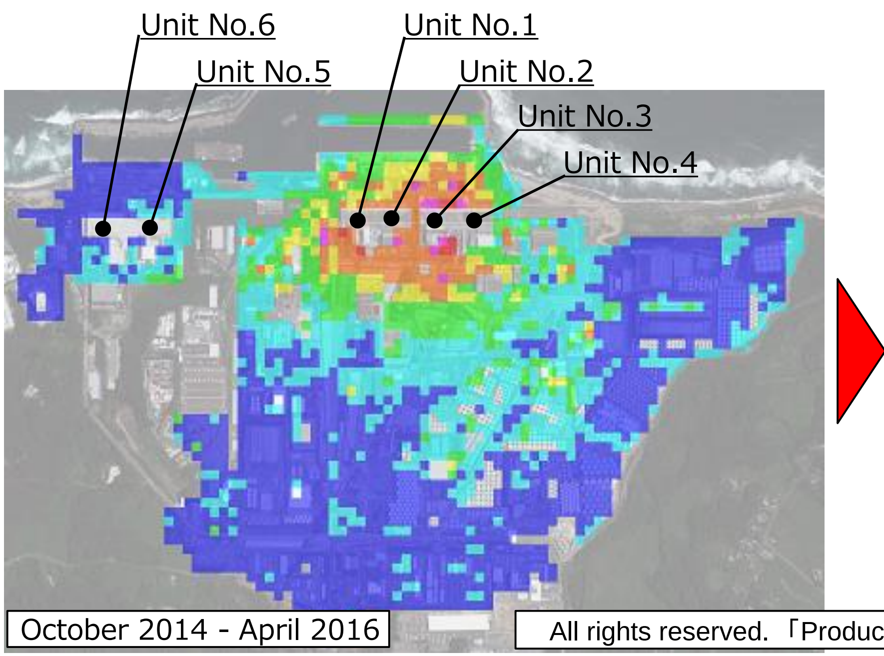


Figure 1　Working environment at 1F before implementation of countermeasures

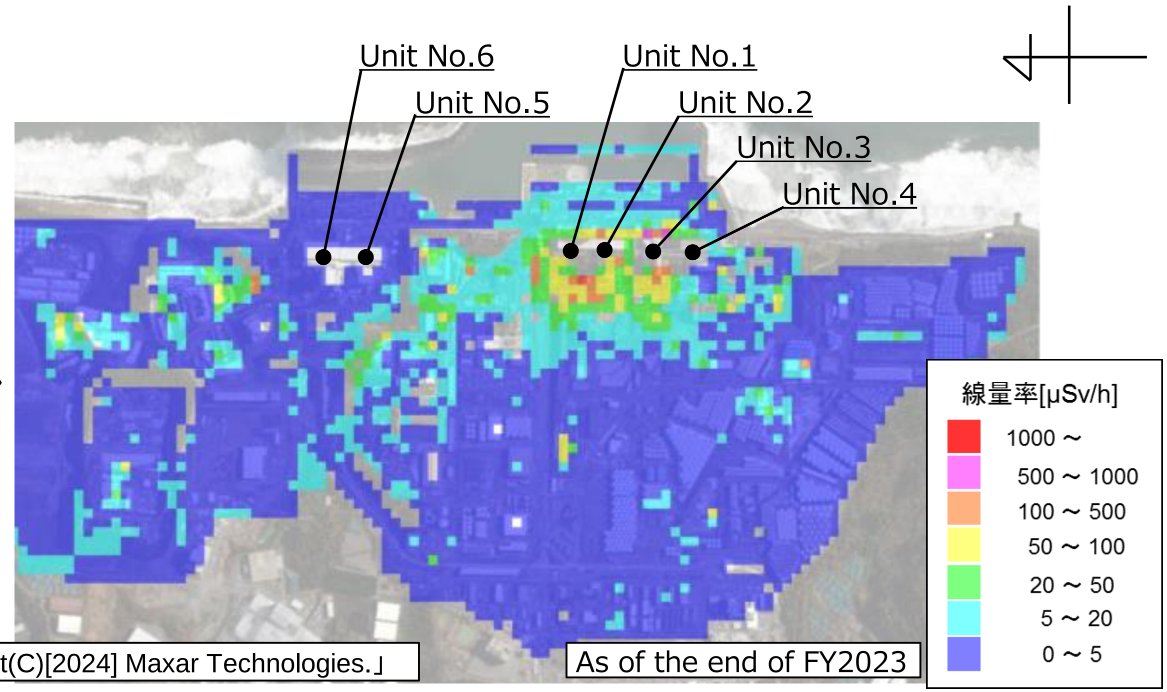


Figure 2　Working environment at 1F after implementation of countermeasures (increase in low dose rate areas)

Working environment at 1F NPS [Dose equivalent rate] (inside Units No.1-3 R/B)

- Units No.1-3, which were in operation at the time of the earthquake, have high dose equivalent rates inside the reactor buildings (R/B) due to damage to the reactor cores.
- The air dose equivalent rates are on the order of several mSv/h to several tens of mSv/h, with some areas exceeding 100 mSv/h.
- In future fuel debris retrieval operations, etc., reducing the dose equivalent rate in the reactor building is an issue.

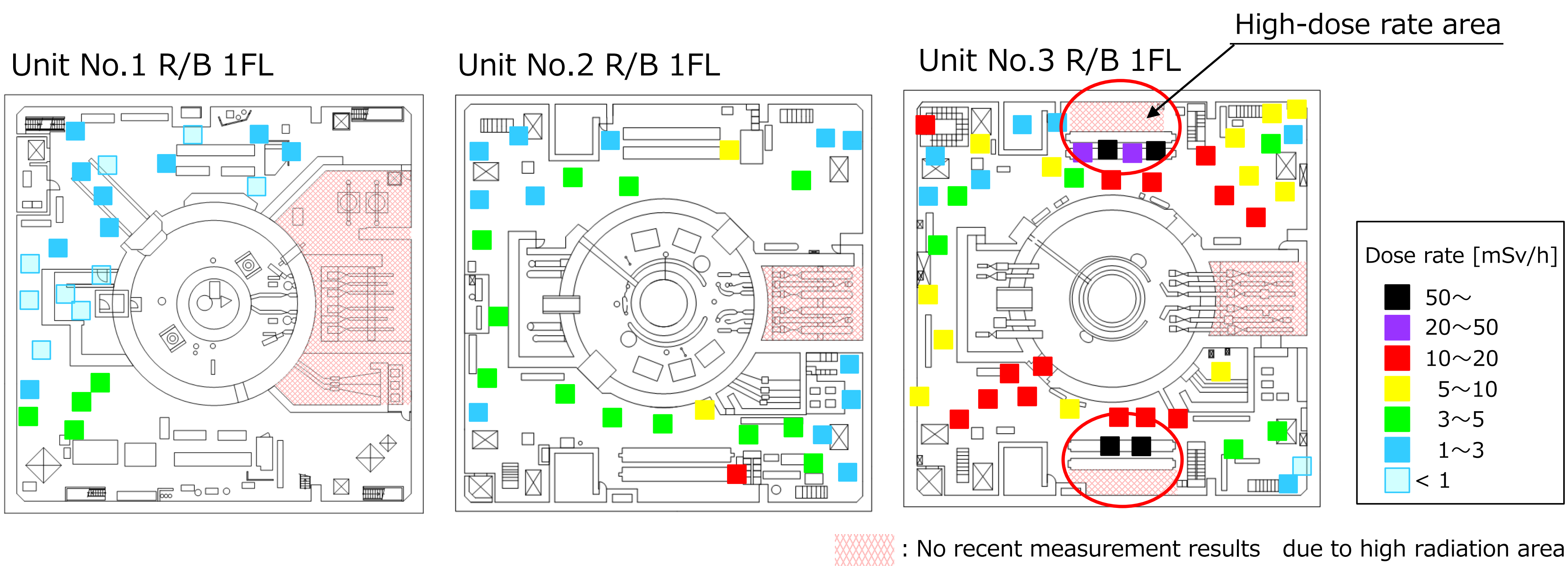


Figure 3 Air dose equivalent rate in the reactor building 1FL of Units No.1-3 (measured in FY2023)

Radiation control at 1F NPS [zone management]

- Based on the contamination situation on the 1F premises, the premises were divided into the following zones from March 2016 (Fig.4).
  - Red zone ： Areas of Units No.1-3 R/B, 1-4 T/B and surrounding areas where stagnant water accumulates.
  - Yellow zone ： Work areas in and around Units No.1-4 where highly concentrated dust and contaminated water are handled.
  - Green zone ： Areas other than the above R and Y zones where protective masks are not required to be worn. (Area where light equipment such as general work clothing and disposable protective masks are allowed to be worn.)
- The Green zone, where no masks are required, covers 96% of the premises.

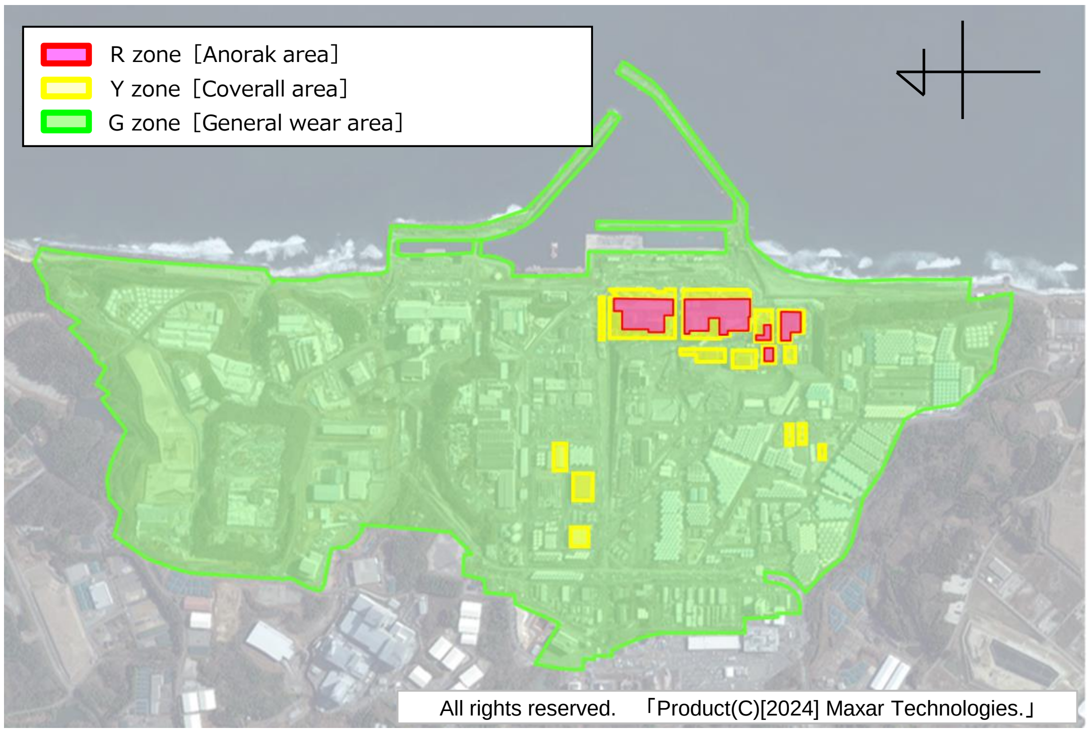


Figure 4 Work area classification of 1F premises (controlled area)

Figure 5 Appropriate protective equipment according to the work area classification

Working environment at 1F NPS [Concentration of radioactive materials in the air]

- Continuous dust monitors have been installed around Units No.1-4 are monitoring 24 hours a day to ensure that the concentration of radioactive materials in the air. It is below the standard for wearing full-face masks levels (2.0E-4 Bq/cm^3) (Fig.6 : ▢), and is on the order of several 1.0E-7 to E-6 Bq/cm^3 under normal conditions.
- Disposable protective masks are not required when moving or performing light work in the G zone outside the protected area around Units No.1-4.

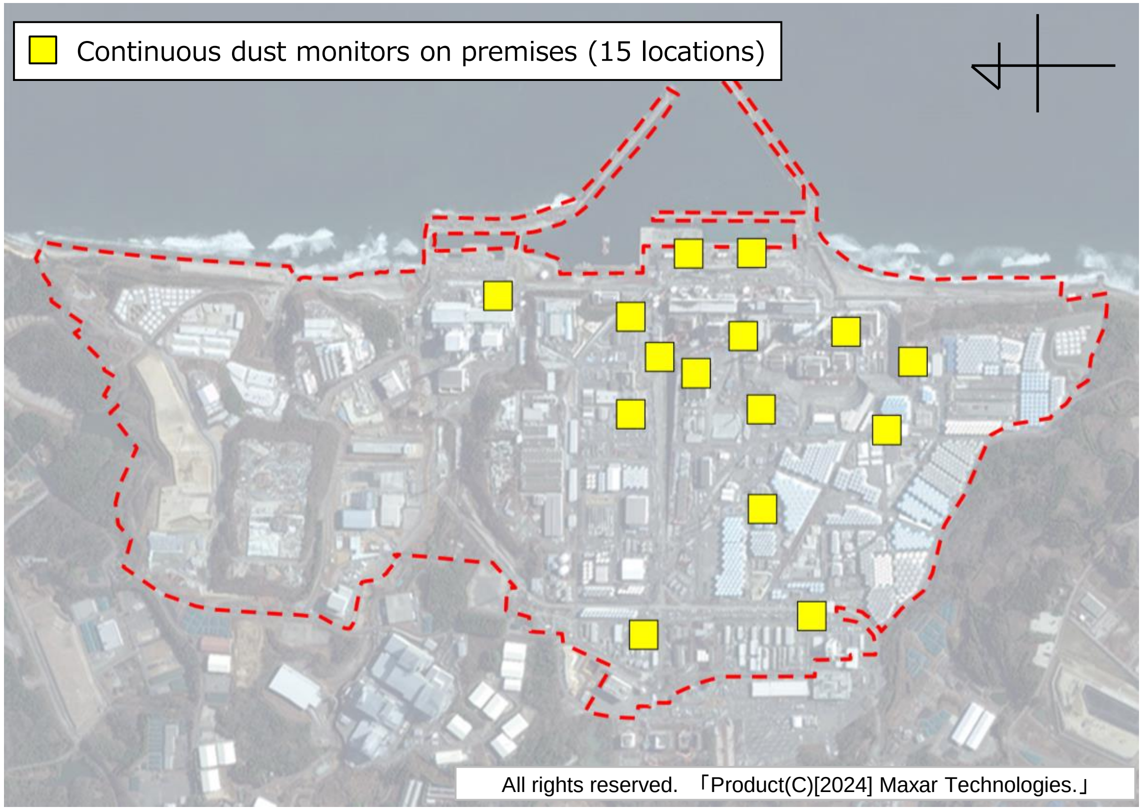


Figure 6　Location of continuous dust monitors on premises on 1F　(controlled area)

Figure 7　Continuous dust monitor on the premises

Figure 8　installation shed

Radiation protection efforts in light of the current situation at 1F NPS [Summary]

- In order to protect the health of workers engaged in decommissioning work in the environment of 1F NPS as described in the previous slides, various radiation protection efforts have been implemented (Table 2).

Table 2 Examples of Radiation Protection Efforts

Item	Effort
Reduction of external exposure dose	Engineering measures (remoteness, installation of shielding, etc.)
	Administrative measures (e.g., mock-up implementation)
Internal exposure	Cooperation agreement with external organization, etc. to strengthen the system in the event of an internal exposure (Activities for in-house production of bioassays)
	Introduction of lung monitor
Preventing the spread of contamination	Installation of highly contaminated changing places at the boundaries of contaminated areas to prevent contamination from spreading
	Reduced risk of contamination adhesion by introducing an improved anorak that covers the entire mask
	Creation and dissemination of alpha maps

External exposure control: Dose reduction measures (Engineering measure_Shielding)

◆ In the “Installation of Oil Diffusion Control Wall for Unit No.3 Startup Transformer Leakage” project, crushed stone and steel plates were placed on the ground surface of the work area to provide shielding against the ground surface, and an L-shaped retaining wall was installed to reduce the dose rate in the work area and reduce exposure doses.

➢ Air dose rate (Max.)

- Work area (before shielding) ： 3.0 mSv/h

▼ 80 % down

- **<u>Work area (after shielding)</u>** ： **<u>0.60 mSv/h</u>**

➢ Exposure Reduction Effects (Actual)

- Before measures ： Approx. 922 man-mSv

▼ 43 % down

- **<u>After measures</u>** ： **<u>Approx. 522 man-mSv</u>**

Figure 9　Shielding with crushed stone and steel plates

Figure 10　L-shaped retaining wall

External exposure control: Dose reduction measures (Engineering measure_Remote)

◆ In the "Unit No.3 T/B shed debris retrieval work," debris retrieval work in work areas with high air dose rates was switched from manned heavy equipment to unmanned heavy equipment, which was operated remotely from low-dose areas to reduce radiation doses.

➢ Air dose rate (Max.)

- Work area (before remoteness) : 20 mSv/h

▼ 99 % over down

- **Work area (after remoteness)** : **0.006 mSv/h**

➢ Exposure Reduction Effects (Actual)

- Before measures : Approx. 1,076 man-mSv

▼ 46 % down

- **After measures** : **Approx. 577 man-mSv**

Figure 11　Unmanned heavy machinery removes high-dose debris

Figure 12　Remote Operation Room

External exposure control: Dose reduction measures (Administrative measure_Mock-up)

◆ In the "low-pressure water washing of sediments in the X-6 penes of Unit No.2," mockups were conducted to improve work efficiency and increase proficiency, thereby reducing radiation doses.

➢ Work time (Estimated)

- Work time (before mock-up) ： 253.5 h

22 % down

- **Work time (after mock-up)** ： **197.0 h**

➢ Exposure Reduction Effects (Estimated)

- Before measures ： Approx. 790 man-mSv

18 % down

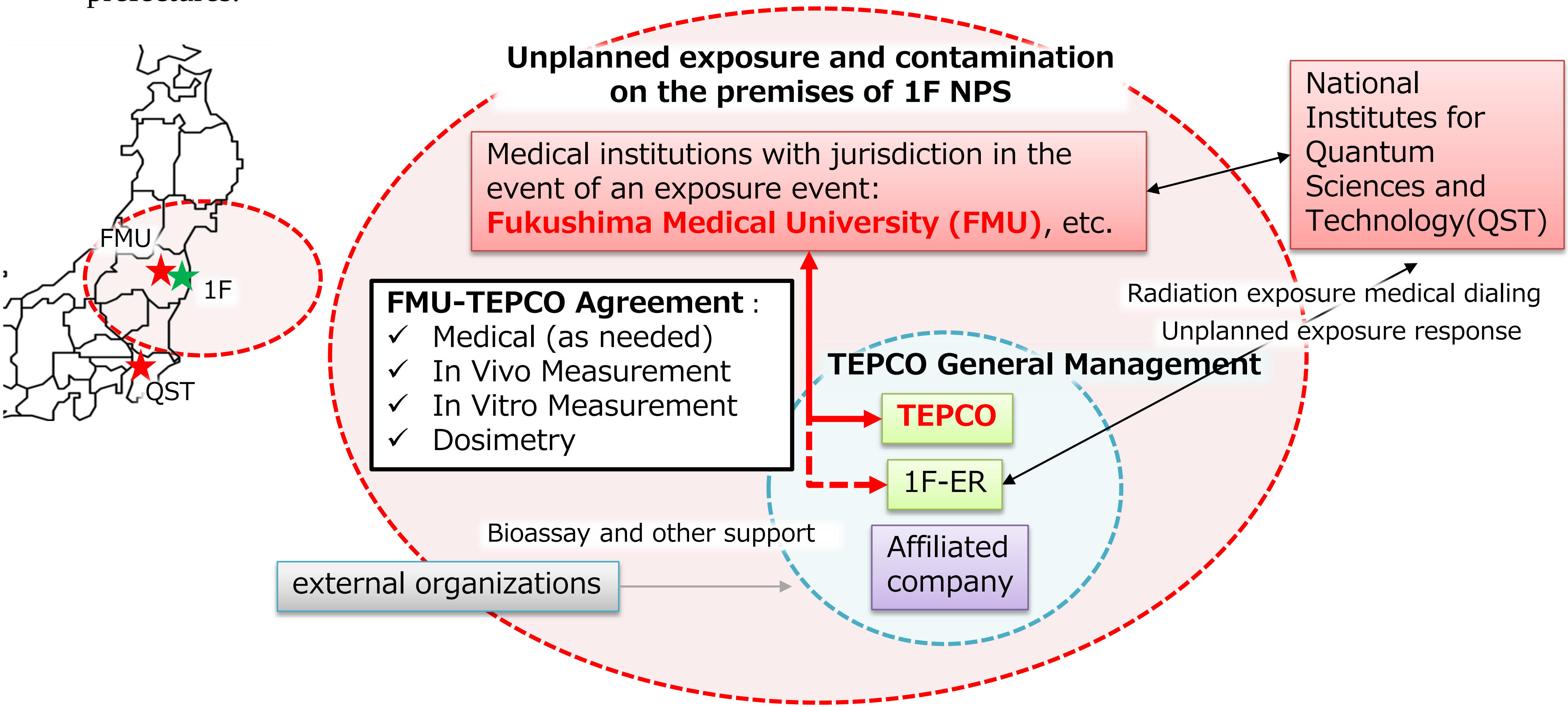
- **After measures** ： **Approx. 650 man-mSv**

Figure 13 Mock-up situation (equipment carry-in/out)

Figure 14 Mock-up status (cable connection and disconnection)

Internal exposure control: Strengthening the system for internal exposure events

◆ In the event of any injuries or illnesses, including internal radiation exposure, we are strengthening our system for trouble events by constructive agreements in advance with medical institutions (FMU) and outside organizations to enable prompt and accurate coordination within Fukushima and neighboring prefectures.



Internal exposure control: Introduction of lung monitor

- Lung monitor is introduced to be measured in case of unexpected intake of α-nuclides in the body during full-scale fuel debris removal operations in the future.
- The lung monitor is used to measure the radioactivity of Am241 in the lungs to help make decisions on the administration of DTPA (actinide nuclides: Pu239, Am241, Cm244, etc.).

Figure 15　Exterior and interior view of lung monitor

Preventing the spread of contamination: Changing the layout of the locations for changing protective clothing and protective equipment

- In the past, the location for changing protective clothing and protective equipment was away from highly contaminated buildings, and there was a risk of contamination spreading on the route after the work was done (Fig.16).

- After the change, the risk of contamination spreading on the travel route was reduced because protective clothing and protective equipment were removed within the zone boundary (Fig.17,18).

Figure 18　Equipment exchange after the change

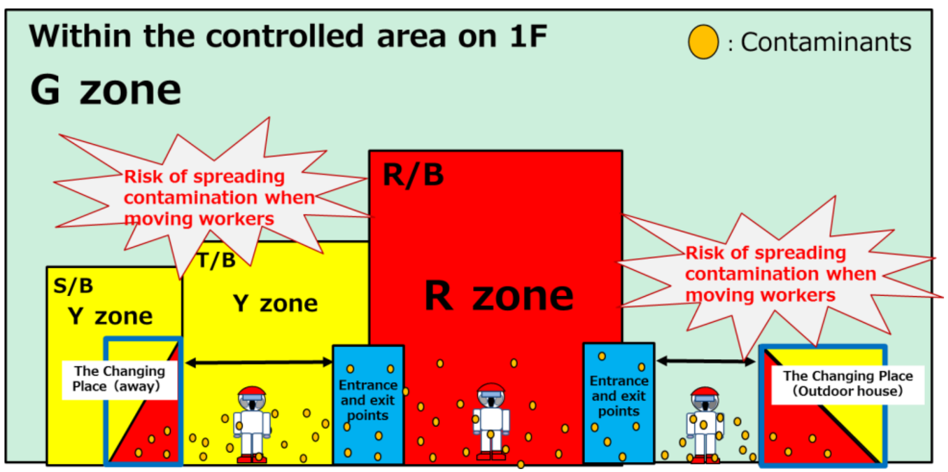


Figure 16　Layout of conventional location for the changing place

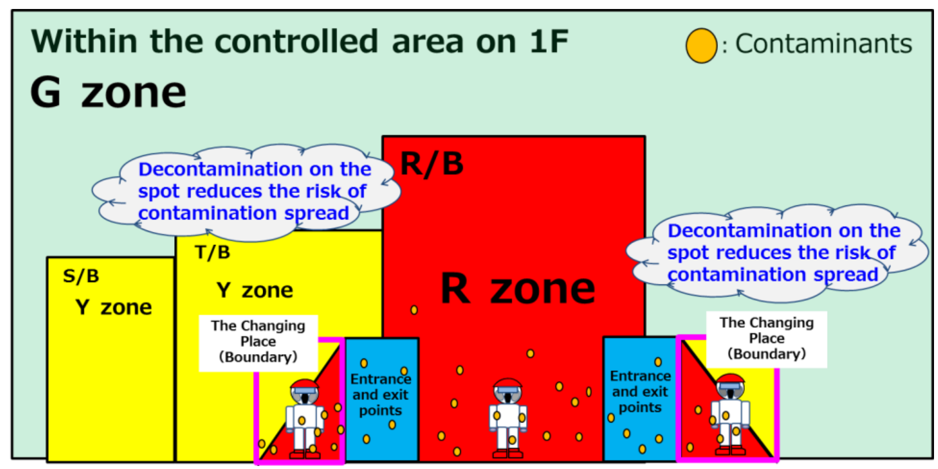
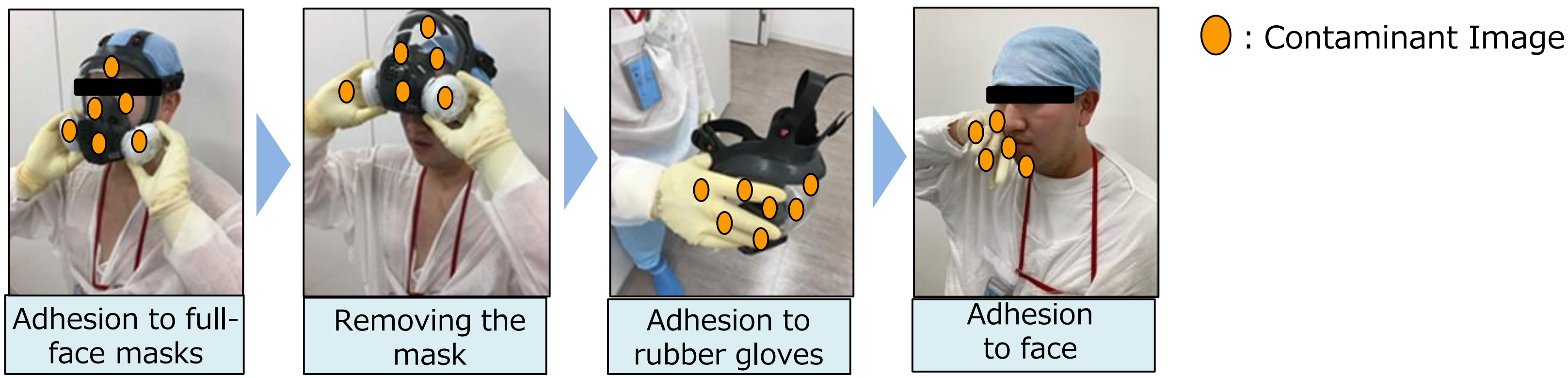


Figure 17　Layout of current location for the changing place

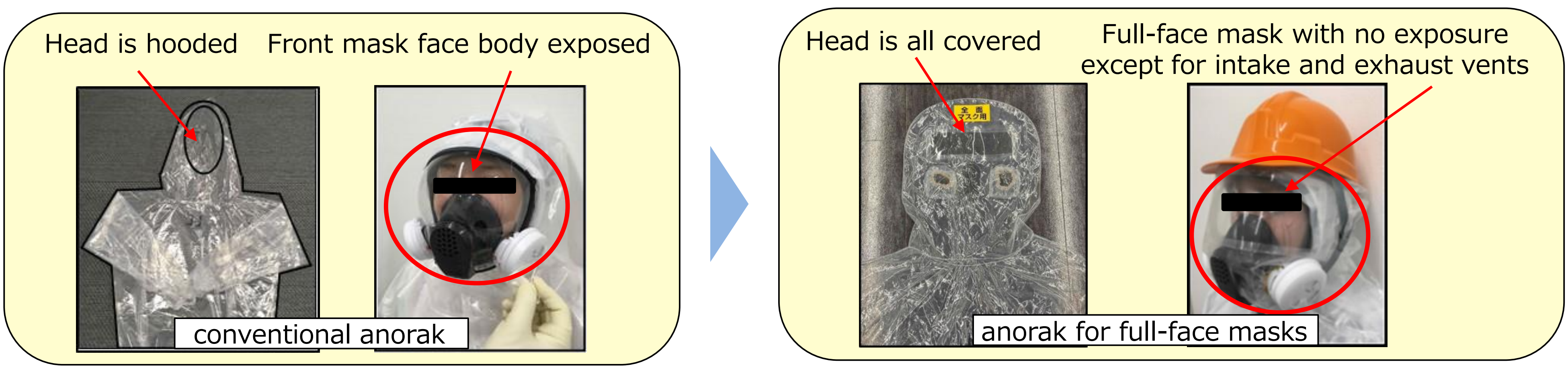
Prevention of contamination spread: Anoraks for full-face masks

- As part of measures to prevent facial contamination and internal exposure, an anorak for full-face masks was manufactured.
- Compared to conventional anoraks, the anorak can cover the entire face, thus reducing the risk of contamination transmission when removing the full-face mask, which is the main cause of facial contamination.

<Diagram of the occurrence of facial contamination in a conventional anorak>



<Differences between conventional anorak and anorak for full-face masks>



Preventing the spread of contamination: Creation and dissemination of alpha maps

- By mapping the on-site contamination status of alpha nuclides that have a large impact on the human body during internal uptake, the contamination status of each location can be visualized, enabling workers to understand the alpha contamination status of the site before work, effecting to an increase in alpha contamination risk sensitivity among workers.

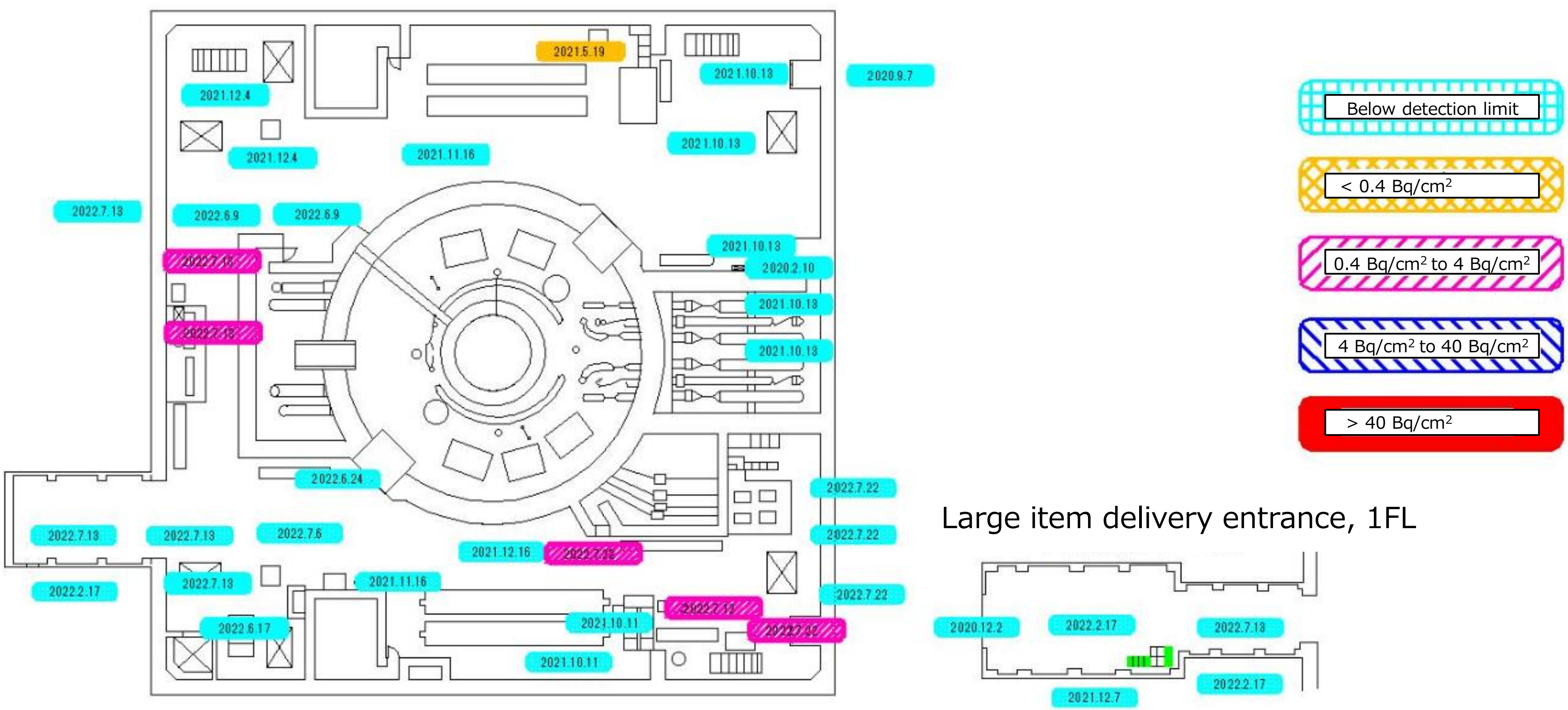


Figure 19　Example of alpha nuclide map created: Unit No.2 R/B, 1FL

Summary

- Thirteen years have passed since the earthquake at 1F NPS, and the working environment, including the dose equivalent rate, surface contamination, and concentration of radioactive materials in the air, has greatly improved compared to immediately after the earthquake.

- Various radiation protection initiatives aimed at protecting the health of workers were implemented to reduce external exposure doses, improve the quality of internal exposure controls, and prevent further contamination spread.

- We will continue to work on various radioprotection efforts to complete the decommissioning work, spent fuel and fuel debris retrieval.