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Review

Impact of the 2024 Noto Peninsula Earthquake on Hokuriku Electric Power Company's Shika Nuclear Power Station in Japan

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Abstract: On January 1, 2024, at 16:10, a magnitude 7.6 earthquake struck the Noto region of Ishikawa Prefecture. The maximum seismic intensity of 7 was observed in Shika Town in the Noto region. About 10 minutes after the earthquake, a major tsunami warning and other related advisories were issued. The Japan Meteorological Agency designated this event as the "2024 Noto Peninsula Earthquake." The Shika Nuclear Power Station, operated by Hokuriku Electric Power Co., is located in the town. This paper reviews the damage to the Shika Nuclear Power Plant over the past month from the perspective of industrial accidents (NATECH) caused by natural hazards, as well as the responses to such events. Although the plant had already implemented safety measures in line with the "New Regulatory Standards" introduced after the 2011 Fukushima Daiichi Nuclear Accident, it was struck by tremors exceeding expectations. While no external radioactive spills occurred, there were reports of water leaks from the spent fuel storage pool, oil leaks from transformers, tsunami impacts, and damage to power transmission lines. Discussions by the Nuclear Regulatory Authority also highlighted issues with radiation monitoring posts. In addition, many evacuation routes were rendered unusable. Of the 11 national and prefectural roads designated as evacuation routes for the Shika Nuclear Power Station, seven were closed due to landslides or cracks. Furthermore, the repeated high intensity and frequency of aftershocks made it difficult for residents to evacuate or take appropriate radiation protection measures, even in their homes or designated shelters. Although the disaster did not escalate into a severe nuclear crisis involving radiation leakage, the adequacy of preparedness, timely communication, and the application of lessons from past events are once again being called into question, highlighting the need to protect lives, property, and the global environment.

Keywords: 2024 Noto Peninsula Earthquake; Hokuriku Electric Power Company; Shika Nuclear Power Plant; Risk Communication; Nuclear Disaster; NATECH

1. Introduction

A magnitude 7.6 earthquake struck the Noto region of Ishikawa Prefecture at 16:10 on 1 January 2024. The maximum seismic intensity of 7 was observed in Shika Town, Ishikawa Prefecture. The epicenter was about 30 km away from east-northeast of Wajima in the Noto region of Ishikawa Prefecture. The earthquake is caused by a reverse fault with a northwest-southeast pressure axis (preliminary report) [1]. Long-period ground motion level 4 was also detected in Noto , and a "major tsunami warning", "tsunami warning", and "tsunami advisory" were issued approximately 10 min after the earthquake in different parts of Japanese coast areas. The earthquake was named the 2024 Noto Peninsula Earthquake in the Japan Meteorological Agency's press release, Second Report on the

Earthquake in the Noto Region of Ishikawa Prefecture at 16:10 on 1 January 2024 [2].

Hokuriku Electric Power Company was out of operation at the time of the earthquake, and it appears to have been damaged by the earthquakes and tsunami [3]. This paper focuses on the damage at the Shika Nuclear Power Station and the response to the damage, and examines the future of nuclear disaster risk communication from the NATECH perspective caused by natural hazards. Since post-311, the Japanese government in 2023 has been steering Japan to maximize the use of existing nuclear facilities due to the recent issues in international energy supply and demand, global warming and other global-scale environments, and Japan's energy resource problems. However, the damage caused by the 2024 Noto Peninsula Earthquake has prompted concern among local governments with existing nuclear facilities and those planning to restart operations, as well as those engaged in developing future nuclear disaster countermeasures. It has become clear that the need for advanced countermeasures and risk communication in preparation for NATECH-like emergencies is more important than ever.

2. Literature Review

Seismic activity in the Noto region of Ishikawa Prefecture had been active since December 2020; the number of earthquakes began to increase around 2018, and activity became even more pronounced around July 2021 as follows: a M5.1 earthquake on 16th September 2021 with a maximum intensity of just under 5; a M5.4 earthquake on 19 June 2022 with a maximum intensity of just under 6; and a M5.0 earthquake on 20 June 2022 with a maximum intensity of just under 6. On 19 June 2022, an M5.4 earthquake with a maximum intensity of just under 6 on the Japanese seismic scale, and a M5.0 earthquake with a maximum intensity of just over 5 on the Japanese seismic scale on the following day, 20 June 2022 (Headquarters for Earthquake Research Promotion, HERP, 2022) [4].

A series of earthquakes continued to hit the Noto Peninsula, and on 5 May 2023, a magnitude 6.5 earthquake occurred near the northeast coastline of the Noto Peninsula, with a maximum intensity of 6 upper, and on 1 January 2024, at 16:10, a magnitude 7.6 earthquake hit the Noto region of Ishikawa Prefecture, with a maximum depth of 7 observed in Shika Town. The maximum depth of 7 was observed in Shika Town, Ishikawa Prefecture. The history of past earthquakes that have hit the Noto Peninsula is as follows:

- 1 August 1729: Noto-Sado earthquake, magnitude 6.6–7.0
- 9 December 1892: Noto earthquake, magnitude 6.4
- 21 September 1933: Nanao Bay earthquake, magnitude 6.0
- 18 October 1985: Noto Peninsula earthquake, magnitude 5.7
- 7 February 1993: Noto Peninsula earthquake, magnitude 6.6
- 25 March 2007: Noto Peninsula earthquake, magnitude 6.9
- 2020–Ongoing: Noto cluster earthquake, maximum magnitude 7.6
- 19 June 2022: Earthquake with epicenter in Noto region, magnitude 5.4
- 5 May 2023: Okunoto earthquake, magnitude 6.5
- 1 January 2024: Noto Peninsula earthquake, magnitude 7.6

These are the major earthquakes that have caused damage. Hiramatsu et al. (2007) [5] pointed out at that time, "The Noto region has experienced six M6 earthquakes in the past 100 years, indicating that it is not necessarily a region of low seismic activity from the perspective of damaging earthquakes", and that the Noto swarm earthquake in 2020, which may be followed by the 2024. The subsequent Noto Peninsula earthquakes in 2020 are also pointed out by the Kanazawa University Joint Research Team KUD (Kanazawa University against Disaster) in 2024 as earthquakes with a new mechanism that has not been known before. The full extent of the earthquake mechanism awaits further clarification [6].

The earthquake in Noto District, Ishikawa Prefecture, Japan, on 1 January 2024, was significant in terms of its magnitude and impact. Table 1 provides an overview of the key details of this event (JMA, 2024).

In our study, we refer to Figure 1, which illustrates the earthquake intensity announced at 16:24 on 1 January. This figure provides crucial insights into the seismic activity observed during this period.

In our study, we refer to Figure 2, which illustrates the tsunami warnings and advisories announced at 16:22 on 1 January. This figure provides crucial insights into the tsunami activity observed during this period.

Table 1. An overview of the earthquake in Noto District, Ishikawa Prefecture, Japan, on 1 January 2024 at 16:10. (Compiled from JMA (2024) website).

Detection Time (Time When the Earthquake was First Detected)	1 January, 16:10
Occurrence Time (Time the Earthquake Occurred)	Approximately 16:10 on 1 January 2023
Magnitude	7.6 (preliminary report)
Occurrence Location	Noto area, Ishikawa Prefecture (30 km east-northeast of Wajima), Shallow-water zone
Mechanism of Earthquake	The preliminary report indicates that the reverse fault type with a pressure axis oriented in a northwest-southeast direction
Seismic Intensity	The Japanese seismic intensity level was 7 in Shika Town, Ishikawa Prefecture, and level 6 to 1 on the Japanese seismic scale from Hokkaido to Kyushu area
Seismic Activity at 5:30 p.m.	Since 16:00, 19 earthquakes of Japanese seismic intensity level 1 or higher have occurred. The intensity level 7 earthquake occurred on one occasion, intensity level 5+ on three occasions, intensity level 5-weak on one occasion, intensity level 4 on eight occasions, and intensity level 3 on six occasions.
Observation of Long-Period Seismic Motion	The long-period 4-level seismic motion was observed in Noto, Ishikawa Prefecture

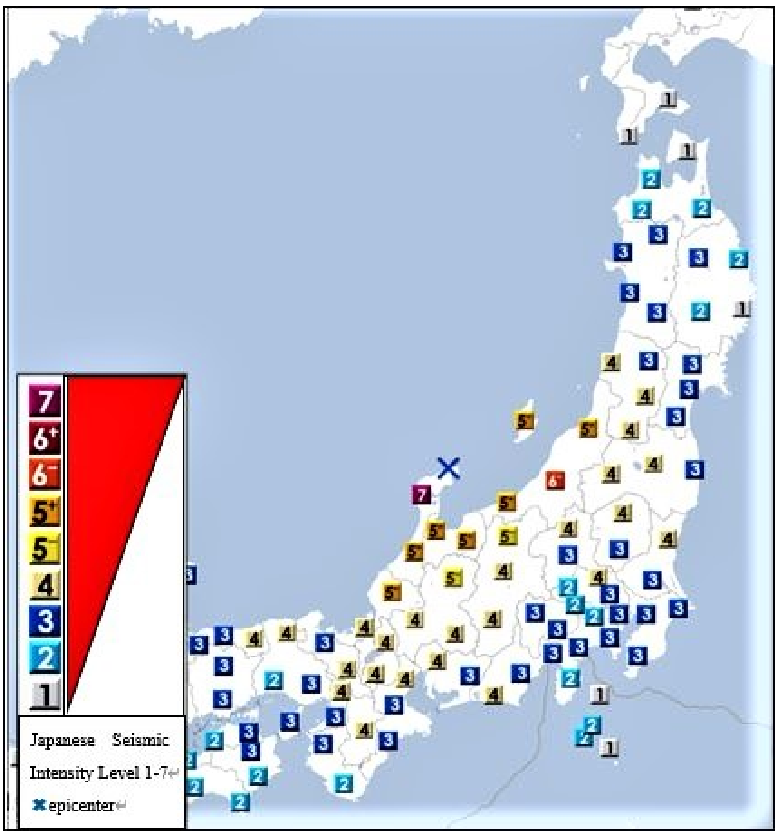

Figure 1. Earthquake intensity announced at 16:24, 1 January (Compiled and modified from JMA (2024) website).

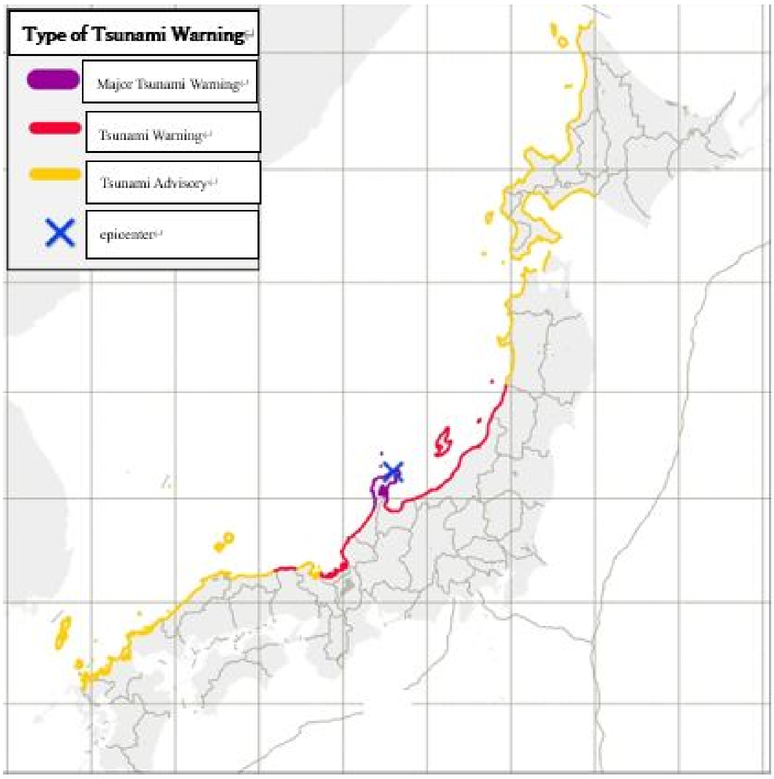

Figure 2. Tsunami warnings and advisories announced at 16:22, 1 January (Compiled and modified from JMA (2024) website).

In our study, we refer to Figure 3, which illustrates the tsunami observation status announced at 5:24 p.m. on 1 January. This figure provides crucial insights into the tsunami observation status during this period.

According to the data and analysis of the Geospatial Information Authority of Japan, GSI, "the land emergence along the coast where the ground raised is caused by the 2024 Noto Peninsula Earthquake (Moment Magnitude7.6) on 1 January. We compared the *Synthetic Aperture Radar*SAR intensity images acquired by *Advanced Land Observing Satellite-2*_/ ALOS-2 satellite before and after the earthquake. The shoreline shifted seaward approximately 200 m at most" (GIS, 2024) [7].In our study, we refer to Figure 4, which is adapted from the GSI website. This figure provides crucial insights into the GIS data for the year 2024.

In our study, we refer to Figure 5, which is adapted from the GSI website. This figure provides crucial insights into the GIS data for the year 2024.

3. Hokuriku Electric Power Company

Shika Nuclear Power Station (hereafter referred to as Shika NPP) Unit 1 was planned in November 1967, construction started in December 1988, first criticality was in November 1992, and commercial operation started in July 1993. Construction of Shika NPP Unit 2 began in August 1999, with first criticality in May 2005 and commercial operation in March 2006. The Shika NPP is located on the west coast of central Shika Town, Hakui County, Ishikawa Prefecture, facing the Sea of Japan. The site is surrounded by rolling hills and covers an area of approximately 1,600,000 m^2. The site is located at 1 Akazumi, Shika-machi, Hakui-gun, Ishikawa about 90 km away from the epicenter of the 2024 Noto Peninsula earthquake, which struck the Noto region of Ishikawa Prefecture at 16:10 on 1 January 2024. The seismic intensity of 7 (magnitude 7.6, extremely shallow-water zone) was observed in Shika Town. In response to the damage caused by the earthquake and tsunami, Hokuriku Electric Power Company announced the comment on its website [8]. In our study, we refer to Figure 6, which is a location map of the Shika NPP. This figure, compiled and modified from the JMA website, provides crucial insights into the geographical positioning of the Shika NPP.

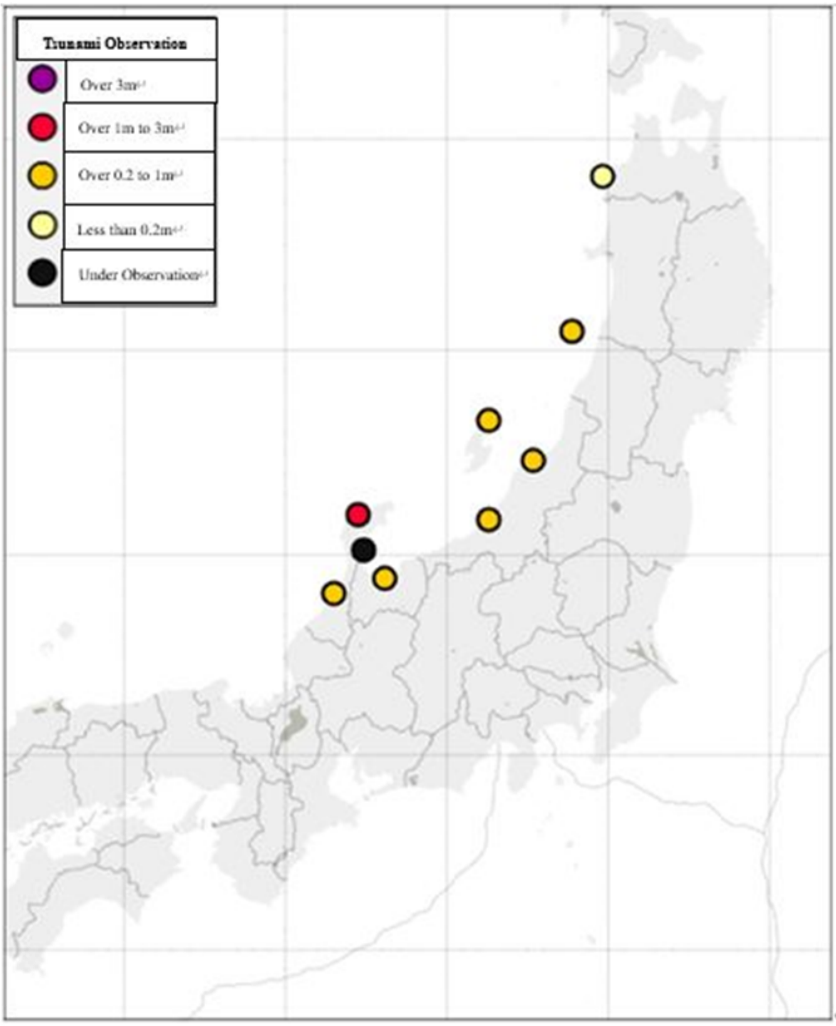

Figure 3. Tsunami observation status announced at 5:24 p.m. on 1 January (Compiled and modified from JMA (2024) website).

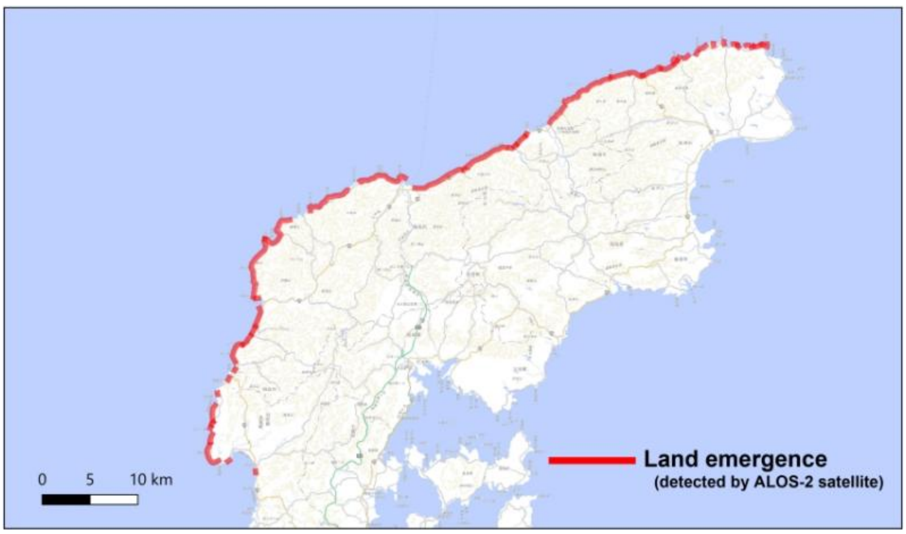

Figure 4. GIS (2024) (Adapted from GSI website).

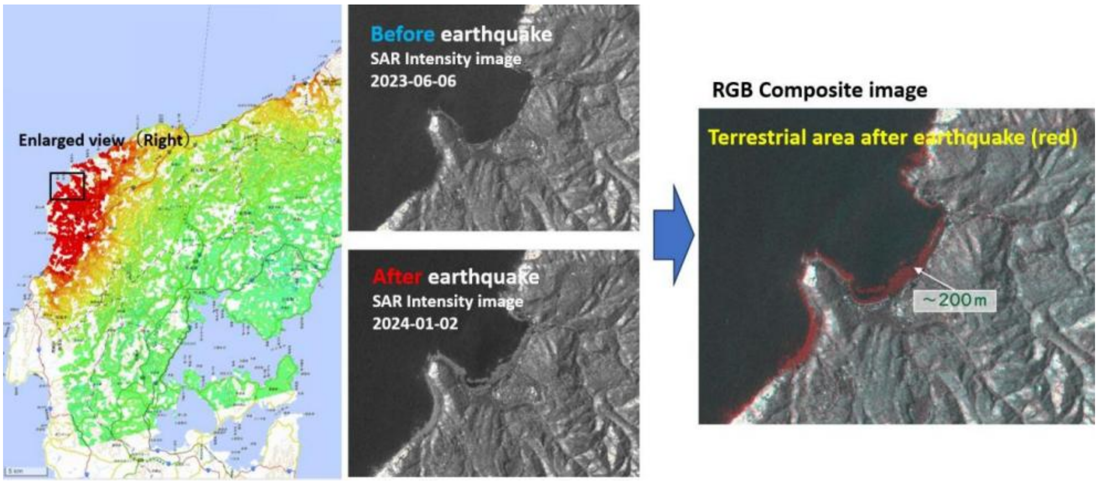

Figure 5. Source:GIS (2024) (Adapted from GSI website).

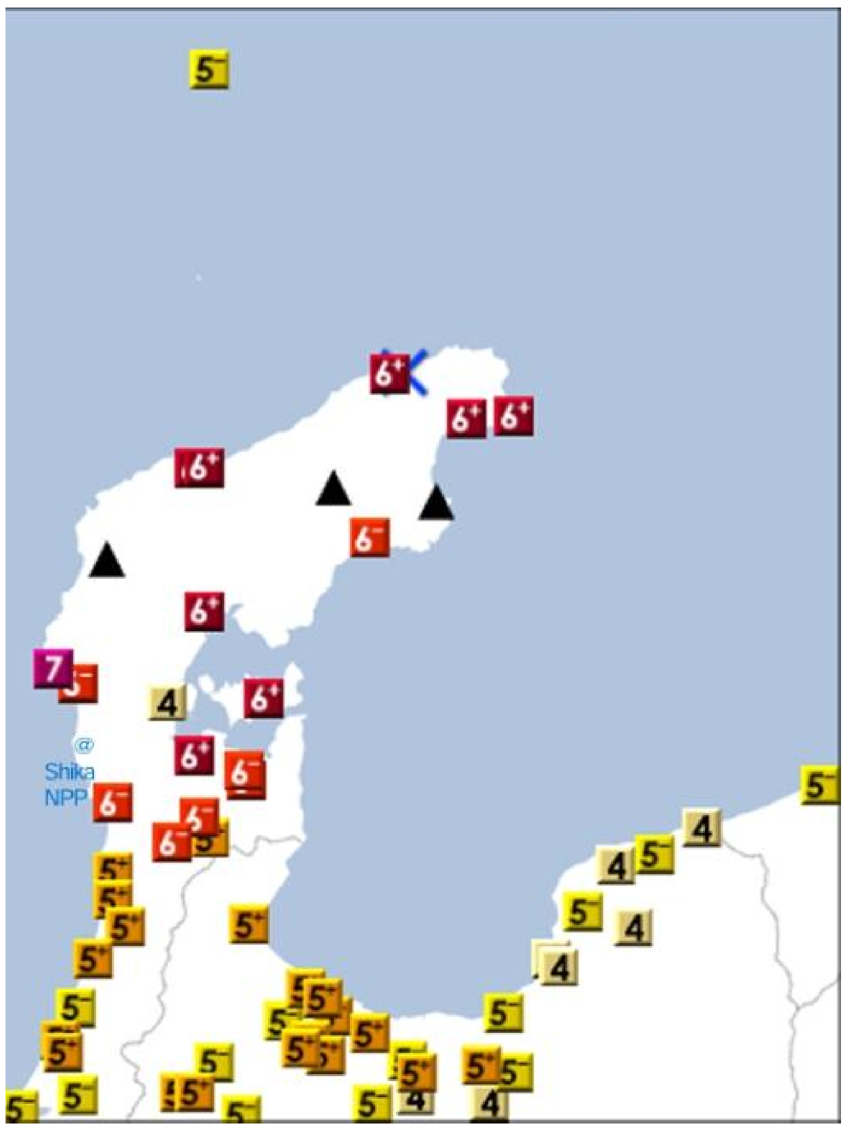

Figure 6. Shika NPP location map (Compiled and modified from JMA (2024) website).

The announcement suggests that in addition to the Shika NPP, Hokuriku Electric Powe Company is also making arrangements for the restoration of power supply, including blackouts and power transmission, restoration of power to evacuation centers, medical and welfare facilities, and the supply of electricity to temporary emergency housing and schools that are expected to be in place in the future. One month has already passed since the earthquake on 1 January 2024, and the full extent of the damage has yet to be revealed. On the other hand, there must be many lessons and issues that have been revealed so far that can be applied in the future. This paper attempts to examine the issues and problems to be addressed in the future by the chronologically following events of the accident from the perspective of NATECH, in which natural disasters cause industrial accidents. The following is an attempt to follow the events of this accident chronologically and to examine the issues and problems that will arise in the future.

4. Chronology of the Shika NPP

Shika NPP Unit 1 started commercial operation in July 1993, and Shika NPP Unit 2 started commercial operation in March 2006. The power plant is located on the west coast of the central part of Shika-machi, Hakui County, Ishikawa Prefecture, which is called "Nakanoto", the central part of the Noto Peninsula, and the eastern site is surrounded by rolling hills and faces the Sea of Japan. An overview of the Shika NPP is as follows Table 2 [9].

Table 2. An overview of the Shika NPP. Compiled from Hokuriku Electric Power Company website.

	Shika Nuclear Power Station Unit 1	Shika Nuclear Power Station Unit 2
Commercial Operation	Since July 1993	Since March 2006
Rated Electrical Output	540,000 kW	1,358,000 kW / In the case of operated with a rectifier plate installed 1,206,000 kW
Reactor Type	Boiling Water Reactor (BWR)	Improved Boiling Water Reactor (ABWR)
Rated Thermal Power	1,593,000 kW	3,926,000 kW
Pressure and Temperature	Approx. 6.9 MPa (approx. 71 kg/cm^2)	Approx. 7.1 MPa (approx. 72 kg/cm^2)
Fuel Type	Low-enriched uranium dioxide	Low-enriched uranium dioxide
Average Enrichment	about 4%	about 4%
Fuel Assemblies	368	872
Reactor Pressure Vessel Total Height/Inner Diameter	Approx. 20 m / 4.7 m	Approx. 21 m / 7.1 m
Thickness	Approx. 120 mm	Approx. 170 mm
Reactor Containment Vessel Type	Pressure suppression type (MARK-I improved)	Pressure suppression type (reinforced concrete)
Total Height / Diameter	Approx. 35 m / Approx. 20 m	Approx. 36 m / Approx. 29 m
Thickness	Approx. 30 mm	2 m (steel lining approx. 6 mm)
Turbine Type	Comb, 4-flow exhaust condensate	Comb, 6-flow exhaust condensate (reheat type)
Rotation Speed	1800 rpm/min.	1800 rpm/min.
Steam Flow	Approx. 3100 tons/h	Approx. 7300 tons/h
Generator Type	Horizontal-shaft cylindrical rotating field 3-phase AC synchronous generator	Horizontal-shaft cylindrical rotating field 3-phase AC synchronous generator
Capacity	600,000 kVA	1,540,000 kVA

5. Safety Measures at Shika Nuclear Power Station

On August 12, 2014, Hokuriku Electric Power Company submitted an application to the Nuclear Regulation Authority of Japan (NRA) to obtain confirmation of the conformity of Shiga Nuclear Power Plant Unit 2 with the new regulatory standards (Hokuriku Electric Power Company 2024.d) [10].

The "New Regulation Standards" referred to here are the "New Regulation Standards" by the Nuclear Regulation Authority, which were reviewed and enforced in July 2013 in response to the accident at the TEPCO's Fukushima Daiichi Nuclear Power Station that occurred when the Great East Japan Earthquake struck, and are not detailed here.

The new regulatory standards significantly strengthen the existing standards ("design standards"), including enhanced standards for earthquakes, tsunamis, and other natural disasters such as volcanic eruptions and tornadoes. In addition, severe accident countermeasures, which have been voluntarily implemented by nuclear operators, have been included in the new regulatory standards as countermeasures against serious accidents, and are now subject to new regulations. Not only new power plants but also existing power plants are required to comply with the new regulatory standards.

Based on the lessons learned from the 2011 accident at TEPCO's Fukushima Daiichi nuclear power plant ("the Fukushima Daiichi NPP), the following safety measures are being implemented at the Shika NPP.

- The estimated tsunami height was changed from 5.0 m to 7.1 m. Confirmation that the tsunami height will not exceed the site elevation of 11 m.
- A 4 m high, 700 m long seawall was constructed at the site elevation of 11 m, bringing the elevation to 15 m. To prevent flooding from water intakes and water outlets, a 4 m high tide barrier was installed at an elevation of 15 m.
- In preparation for the event of a tsunami that overtopped the seawall, the doors of buildings with important equipment were replaced with watertight doors.
- Reinforcement of external power supply so that electricity can be sent directly from all power lines to the power plant. Secure power supply for equipment to prevent core damage in the event of a serious accident, etc.
- Secure a water source to keep the reactor cool for a long period. Enhancement of functions to cool the reactor and containment vessel, as well as functions to cool the spent fuel storage pool.
- Install equipment to prevent hydrogen explosions. Install venting equipment with filters to reduce the release of radioactive materials. Install a water discharge system to discharge a large volume of water to control the diffusion of radioactive materials in response to a major accident and to prevent fires.
- Establishment of an emergency response building and an additional emergency response station (command area).
- Other safety measures and environmental monitoring functions were strengthened, and deployment of heavy equipment and materials for debris removal.

Next, let us look again at the damage to the Shika NPP by the 2024 Noto Peninsula Earthquake, even with these safety measures in place.

6. Damages to Shika NPP

Below is a series of nuclear press releases reporting on the damage during the month of January 2024. The dates and titles are shown [11].

In our study, we refer to Table 3, which is the press release on Nuclear Energy in January 2024 by Hokuriku Electric Power Company. This table provides crucial insights into the nuclear energy status during this period.

At the time of the 2024 Noto Peninsula Earthquake, Shika nuclear power plants No. 1 and No. 2 were undergoing routine inspections and were not in operation due to the Great East Japan Earthquake that occurred on 11 March 2011, and the Fukushima Daiichi Nuclear Power Plant accident. What happened and what measures were taken at that time are summarized below, focusing on the report "*The Effects of the 2024 Noto Peninsula Earthquake on Shika NPP*". The following is a summary in chronological order within one month period.

6.1. Events on 1 January 2024

At 16:10 on 1 January 2024, an earthquake of magnitude 7 (7.6 on the Richter scale and with an extremely shallow epicenter) occurred in the Noto district of Ishikawa Prefecture, with intensity 7 (above 5 on the Richter scale and 399.3 gals at the 2nd basement level of the Unit 1 reactor building) observed in Shika Town.

Table 3. Press release nuclear energy in January 2024 by Hokuriku Electric Power Company.

Date	Title
1 January 2024	Effects of the Noto Peninsula Earthquake in Ishikawa Prefecture on Shika Nuclear Power Station
2 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station
2 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station
2 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station
5 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station (5th report)
7 January 2024	6 January 2024 Earthquake in Noto District, Ishikawa Prefecture (flash report)
7 January 2024	The Influence of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station (6th report)
9 January 2024	Status of Shika Nuclear Power Station due to the Noto Peninsula Earthquake of 2024
10 January 2024	10 January 2024 Earthquake off Noto Peninsula, Ishikawa Prefecture at 4:02 a.m. (flash
10 January 2024	Shika NPP Monthly Report (for December 2023)
10 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station (7th report)
12 January 2024	Effects of the Noto Peninsula Earthquake of 2024 on Shika Nuclear Power Station (8th report)
12 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 16:01 on 12 January 2024 (flash report)
12 January 2024	Earthquake Occurrence in Noto District, Ishikawa Prefecture at 21:10 on 12 January 2024 (quick report)
13 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 4:04 a.m. on 13 January 2024 (flash report)
13 January 2024	Effects of the 2024 Noto Peninsula Earthquake on Shika Nuclear Power Station (9th report)
14 January 2024	Earthquake in the Noto district, Ishikawa Prefecture at 0:01 on 14 January 2024 (flash report)
17 January 2024	Automatic Shutdown of the Emergency Diesel Generator at Shika Nuclear Power Station Unit 1 during test operation
23 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 2:13 pm on 23 January 2024 (flash report)
23 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 13:40 on 23 January 2024 (flash report)
23 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 13:40 on 23 January 2024 (flash report)
24 January 2024	Earthquake in Noto District, Ishikawa Prefecture at 6:06 a.m. on 24 January 22024 (preliminary report)
30 January 2024	Current Status of Shika Nuclear Power Station since the Noto Peninsula Earthquake of 2024 (as of January 30)

- Spent fuel storage pool water leaked from the floor on the 4th floor of the Unit 1 reactor building. As a result, the fuel pool cooling and purification system pumps were temporarily stopped and restarted at 16:49.
- At 19:23, the operation to switch to an alternative standby power transformer was carried out. The switchover to the backup power transformer was automatically completed. The cause of the problem is currently under investigation. The presence or absence of other abnormalities is also being checked. No change in monitoring post readings. No external radiation effects.

6.2. Events on 2 January 2024

Main inspection status currently for Unit 1 (3 items) and Unit 2 (3 items).

1. Unit 1 and 2 transformers

   Unit1: Oil leakage from the Unit 1 startup transformer, operation of the pressure release plate, and startup of the spray fire extinguishing system. An on-site inspection of the transformer confirmed a leak of approximately 3600 L (estimated) of insulating oil from the transformer. However, the insulating oil was contained within a weir, and there was no external impact. It was confirmed that the pressure release board of the Unit 1 startup transformer operated, and the spray fire extinguishing system was manually activated at the time of the earthquake. The cause of the pressure release board operation is under investigation. No fire was reported. Unit2 : An on-site inspection of the transformer confirmed that approximately 3500 L (estimated) of insulating oil had leaked from the transformer. The insulating oil was contained within a weir, and there was no external impact. The cause of the activation of the spraying fire extinguishing system and the operation of the pressure release plate is under investigation. No fire occurred.
2. Spent fuel storage pools in Units 1 and 2

   Spent fuel storage pool water in Unit 1 was scattered. The amount of water scattered was about 95 L and the radioactivity level was about 17,100 Bq. Unit 2 spent fuel storage pool water: no external radioactive effects were observed.

3. Water level in the surge tank of the turbine auxiliary coolant system of Unit 1 dropped. Cooling water leaked from the cooling coils of the ventilation and air conditioning system in the reactor and turbine buildings, and a drop in the water level was confirmed. The leakage was stopped by identifying the leakage point and closing the valves.
4. A "large elongation gap" alarm occurs in the low-pressure turbine of Unit 2. It is assumed that the "large elongation gap" alarm was triggered by the shaking caused by the earthquake. The presence or absence of abnormalities inside the turbine is also confirmed.

6.3. Events on 3 January 2024

The Shika Nuclear Power Station is continuing to conduct facility inspections and would like to inform you of the following newly confirmed damage since the events have been reported.

1. Unit 2

   Oil leaks from the excitation power transformer. The insulating oil is contained within a weir and has no external impact. The leaked oil is estimated to have been discharged through a conduit due to the operation of a pressure release valve installed on the top of the transformer. The national government, Ishikawa Prefecture, Shika Town, and other related local governments have been notified of this matter. Transformer to supply power to the generator coils (exciter) that generate the magnetic flux required for power generation.

2. Rise in seawater level in Intake Tank No. 2

   This was due to a rise of approximately 3 m in the intake channel of the submarine tunnel. This is a rise in the water level in the intake tank through the intake channel of the undersea tunnel and does not represent an accurate measurement of the tsunami height at the sea surface. The power plant site is located at a height of 11 m and is protected by a 4-meter-high sea dike/wall, so there was no impact on the power plant facilities.

6.4. Events on 5 January 2024

The fifth report of the day confirms the damage to date and summarizes the response to it. Meanwhile, regarding the insulating oil leak from the main transformer of Unit 2 reported on January 2, the leaked insulating oil has been corrected to approximately 19,800 liters (approximately 24,600 liters including water), and its treatment has been completed.

The January 2 report indicated that the estimated amount of leaked oil was (approximately 3,500 liters).

The reason for this increase was that the leakage was assumed to be limited to the amount of oil in the conservator (oil deterioration prevention device), which is located higher than the leak site. In reality, a part of the transformer body is also located higher than the leak site, and the insulating oil in this area also leaked.

Other measures are as follows:

1. The operation of the transformer in Unit 1 and the pressure release plate of the main transformer in Unit 1 were checked. No oil leakage was found because of this.
2. Settlement of the pavement concrete at the reclaimed portion of the landing area occurred.
3. Settlement of the foundation of the Unit 1 water discharge tank and the seawall of the Unit 1 auxiliary cooling drainage connection tank occurred.
4. Steps occurred near the area where the high-voltage power supply truck of Unit 1 is used.

6.5. Events on 7 January 2024

A small amount of oil film was observed in the gutter and on the road around the main transformer of Unit 2. An oil slick (Approx. the ratio of 5 meters to 10 meters) was also observed floating on the sea surface in front of the Shika Nuclear Power Station. The oil slick was immediately treated. There is no abnormality in the oil leak detectors installed at the locations where oil is stored in the radiation-controlled area, and this oil film is not the oil in the radiation-controlled area. In addition, there is no change in the values of the monitoring posts installed at the power plant, and there is no external radiation effect.

6.6. Events on 9 January 2024

On this day, the report is not titled "*Effects of the 2024 Noto Peninsula Earthquake on Shika Nuclear Power Station* (7th report)", but rather "*Current Status of Shika Nuclear Power Station due to the 2024 Noto Peninsula Earthquake*", which summarizes the current status of damage to the Shika Nuclear Power Station, including the power transmission system, due to the 2024 Noto Peninsula Earthquake. The report includes new information on the tsunami and damage to the external power supply.

- Water level gauge in the intake tank of Unit 2 The water level rose about 3 m (around 17:45) (already reported in the 4th report).
- Near the water intake]. The water level rose about 3 m (around 17:45) (reported in this report).
- Wave height gauge near the landing site. The water level rose about 3 m (around 17:45) (announced in this report).

The power lines leading to the Shika Nuclear Power Station were inspected and the following were confirmed (Shika Nuclear Power Line 275 kV 2 lines). No abnormality was observed.

6.7. Events on 10 January 2024

Since no new oil spillage was confirmed in the gutter around the main transformer of Unit 2, the drainage gate for rainwater was opened on 9th January to drain rainwater that fell on the premises. However, at around 12:00 p.m. today, an oil slick (Approx. the ratio of 100 meters to 30 meters, estimated 6 L) was found floating in the gutter around the main transformer of Unit 2. The drainage gate was promptly closed, and an oil fence was installed in the coastal area. No abnormality was found in the oil leak detectors installed at the locations where oil is stored in the radiation-controlled area, and the oil film was not oil in the radiation-controlled area again. In addition, there is no change in the values of the monitoring posts installed at the power plant, and there is no external radiation impact.

6.8. Events on 12 January 2024

The integrity of the power transmission route from the internal power supply system of Unit 2 has been confirmed once again, and preparations are being made to replace missing insulators and jumper wires.

6.9. Events on 13 January 2024

As announced on 12 January, the replacement of one missing insulator and one broken strand of jumper wire (connecting insulators in front of and behind the tower) on the Akazumi line (66 kV, 1 line) that transmits power to the Shika Nuclear Power Station was started at 7:25 a.m. today (13 January) and completed at 11:47 a.m. The repair work was completed at 11:47 a.m. today (13 January). With the completion of this repair work, the three external power supply lines (Akazumi line (1 line, 66 kV)) and Shika nuclear line (2 lines, 275 kV) are back to the state where they can receive power.

6.10. 17 January 2024

At Shika Nuclear Power Station Unit 1, a trial run of the high-voltage core spray diesel generator, one of the emergency diesel generators, was conducted at 16:58 today as a security check following the Shika Town seismic intensity of 5 (intensity 2, 24.5 gals) that occurred at 18:42 on 16th January. The diesel engine was being started and the generator was being connected to the plant's power supply system, when it automatically stopped at 5:13 p.m. The cause is currently under investigation.

The above is a report on the impact of the earthquake at the Shika Nuclear Power Station, and a summary of the status of the Shika Nuclear Power Station since the Noto Peninsula Earthquake of 2024 (as of 30 January), which was published on 31 January 2024.

As of 1 February 2024, one month after the earthquake, there were a total of 22 nuclear press releases, including bulletins and monthly reports. The press releases titled *Effects of the Noto Peninsula Earthquake of 2024 on the Shika Nuclear Power Station* existed in 1–13 January 2024 (9th report). In the press releases titled *Status of Shika Nuclear Power Station after the Noto Peninsula Earthquake of 2024* on 9th January and 30 January 2024, two press releases were issued during the past month, in which the responses and results to the events caused by the earthquake and tsunami were summarized. On the other hand, the 17th January 2024, press release titled *Automatic Shutdown of Emergency Diesel Generator at Shiga NPP Unit 1 during Trial Operation* describes an incident that occurred because of safety confirmation measures taken after the recent earthquake.

According to the past press release history, the monthly report is titled *Shiga NPP Monthly Report* and is issued once a month or around the 10th of the following month, excluding Saturdays, Sundays, and holidays, with information on accidents, breakdowns, etc., and operation and maintenance at Shiga NPP for the current month. If the 10th is a Saturday, Sunday, or holiday, the report is moved up to the day before or two days before. Therefore, the contents of the monthly report on 9th February 2024, Friday, will be the focus of attention from now on.

7. Future Issues and Challenges

The impact of the 2024 Noto Peninsula earthquake and tsunami on the Shika NPP has been described above. No serious NATECH damage, such as radiation leakage, has been confirmed so far because Units 1 and 2 of the Shika NPP have not been in operation since 11 March 2011, and have been undergoing routine inspections. However, the Noto Peninsula was hit by more earthquakes and tsunamis this time than previously assumed, with the second basement floor of the Unit 1 reactor building measuring 399.3 gals on the 5+ intensity on the Japanese seismic scale. (57th Nuclear Regulation Authority, 2024.a) [12].Furthermore, it has been reported that the earthquakes were caused by a new mechanism that is unprecedented in the past: fluid released from an old magma reservoir is believed to have been involved in this earthquake swarm. (Okada, T., Savage, M.K., Sakai, S. et al. 2024) [13].

How should we prepare for such unknown natural disasters and associated NATECH accidents that exceed our expectations?

Many buildings collapsed and many residents were crushed to death by the earthquake. Even if they did not collapse, the earthquake resistance of houses that were repeatedly hit by violent tremors is naturally low, and people are forced to live in evacuation centers, unable to return to their own homes. The earthquake caused the ground to rise and sink, generated tsunamis, landslides, collapsed roads, liquefaction, power and water outages, fires, and isolation of villages as well.

In addition to the damage caused by natural disasters, from a NATECH perspective, how will the facts of this oil leakage in the nuclear power plant, the damage and breakage of the power lines leading to the Shika NPP, and the rupture of communication means be used for future disaster prevention?

The 60th regular meeting of the Nuclear Regulation Authority was held on 7 February 2024, in Roppongi, Minato-ku, Tokyo. The fourth item on the agenda was "Agenda Item 4: Current Status of Shika Nuclear Power Station after the 2024 Noto Peninsula Earthquake and Future Responses," which included a report on the damage to the Shika Nuclear Power Station caused by the earthquake and tsunami [14]. Among the issues discussed was the problem of monitoring post malfunctions. 17 of the 18 monitoring posts had malfunctioned, and although measurements were being taken, it was reported that information could not be shared. Although all monitoring posts, including temporary ones, have been restored at this time, the likely cause of the problem was a malfunction in wired and wireless communications. No report of this event could be found on the Hokuriku Electric Power Company website. This is because the organizations responsible for collecting and analyzing data from monitoring posts around nuclear power plants are mainly the Ministry of the Environment and local governments. If information is not shared and disclosed appropriately, it may not lead to prompt evacuation actions in the event of a nuclear disaster. In some cases, this may lead to the consideration of taking stabilized iodine tablets or other medications to avoid the risk of radiation exposure. This is the most necessary and important information to protect lives and property, as the case of the Fukushima Daiichi nuclear power plant accident occurring on 11 March 2011, causing the Great East Japan Earthquake and Tsunami, and subsequent Nuclear Disaster as a NATECH. The question of how and when to communicate this information is a new issue for risk communication in the future, and this case may be said to have once again brought this issue into sharp relief. Kyodo News (2024.a) reported that the earthquake had also caused many of the evacuation roads, which are key to nuclear disaster prevention, to be closed [15]. Among them, 11 national and prefectural roads were designated by Hokuriku Electric Power Company as evacuation routes in the event of a major accident at the Shika NPP, 7 of them were closed due to collapses and cracks by the quake in this time On the other hand, The evacuation plans established by the national and local governments have been drastically revised since the Fukushima Daiichi Nuclear Power Plant accident caused by the Great East Japan Earthquake and Tsunami 311. And the Nuclear Disaster had occurred as a NATECH compound disaster under this evacuation preparedness and regulations on that time.

In our study, we refer to Figure 7, which is a collection from the Great East Japan Earthquake and Nuclear Disaster Museum—Emergency Preparedness Poster for Nuclear Power Accidents. This figure provides crucial insights into the emergency preparedness for nuclear power accidents. Asapted with permission from the Great East Japan Earthquqke and Nuclear Disaster Memorial Museum (2024) [16].

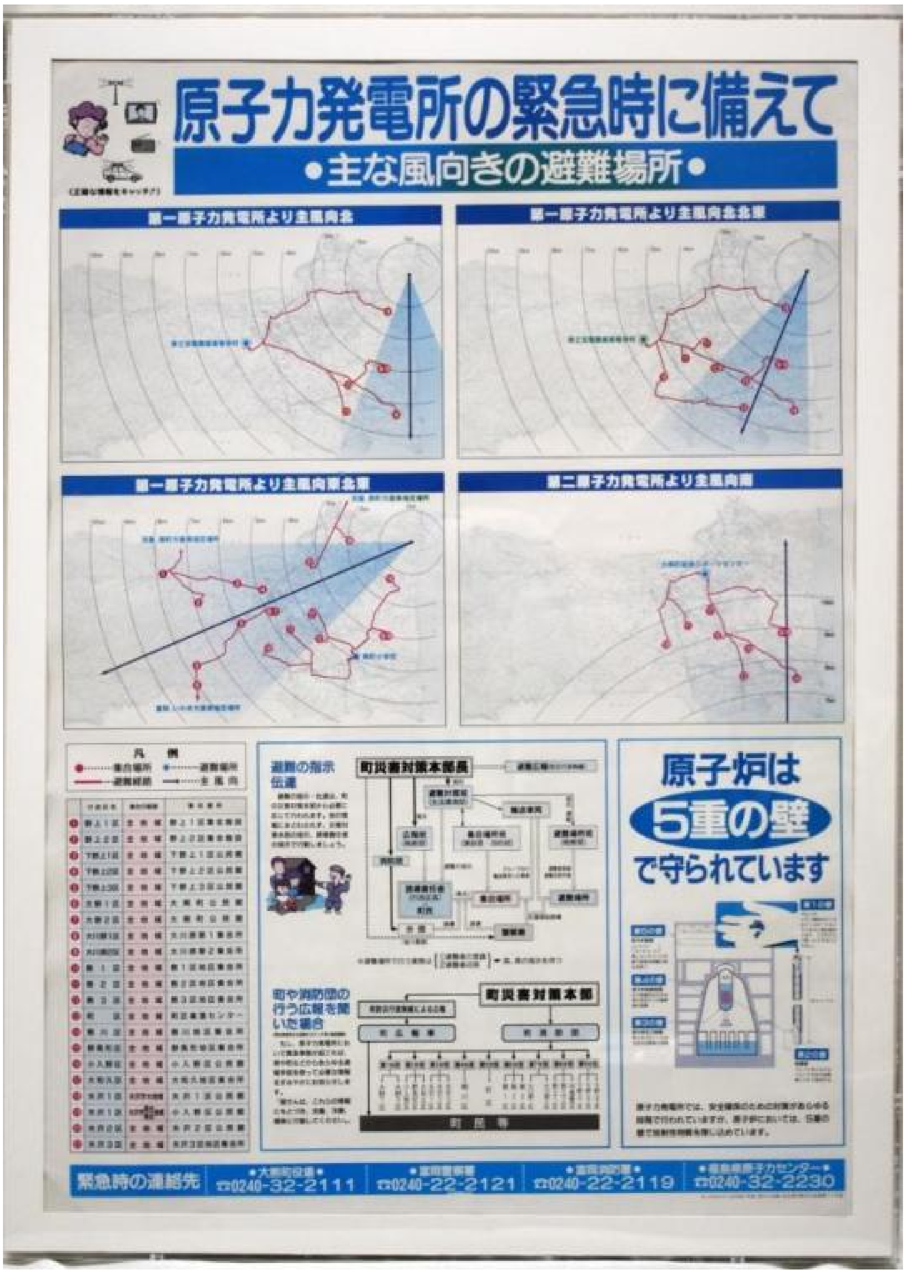

Figure 7. Collections of the Great East Japan Earthquake and Nuclear Disaster Museum—Emergency Preparedness Poster for Nuclear Power Accidents.

This poster was created in 1995 by the town of Okuma in Fukushima Prefecture, where the Fukushima Daiichi nuclear power station was located. It is illustrated the wind direction and evacuation site in the event of a release of flying radioactive materials, as hypothesized at the time of the accident. However, following the Great East Japan Earthquake and Tsunami on 11 March 2011, the radioactive plume began to drift in a northwesterly direction. Consequently, the government issued an evacuation order for a radius of 10 km, 20 km, and 30 km from the nuclear power plant that had been damaged in the accident. During this period, the residents were not provided with accurate information, and the police officers and firefighters who were guiding the evacuation instructed them to run away and go west. It is evident that the residents were compelled to evacuate. Because there was not enough countermeasures then.

The new evacuation plans are based on the Regional Disaster Prevention Plan, which is based on the Nuclear Emergency Response Guidelines. Specifically, residents are living in a 5 km radius of the plant are to evacuate first, while those who are living in a 5–30 km radius are to evacuate temporarily to their homes or evacuation shelters, and then evacuate to areas with high radiation levels.

However, it is also pointed out this time that due to the intensity and repeated frequencytremors , even houses and designated evacuation shelters, which are indoor evacuation sites, have been heavily and frequently damaged, making it difficult to establish an indoor evacuation and radiation protection system within a 30 km radius due to a nuclear disaster. In fact, among the 21 radiation protection facilities located within a 30-kilometer radius where the elderly and others are temporarily evacuated in the event of an accident, the Noto Peninsula earthquake damaged or caused abnormalities at 6 of them. Two of these facilities were closed because they could not be used, and the other two facilities, including hospitals, had to relocate patients. Water was cut off at a total of 21 facilities. Some people are concerned that the government has failed to fulfill its responsibility to protect residents in need of assistance in emergency situations.by Kyodo News (2024.b) [17].

8. Conclusions

Based on these results, the Nuclear Regulation Authority established the Study Team on the Operation of Shelter-in-Place in the Event of a Nuclear Disaster for the purpose of studying the most effective way to operate the protective measure of shelter-in-place, and its first meeting was held on 22 April 2024. (Nuclear Regulation Authority, 2024.c) [18]. At the meeting, the following four issues will be discussed over the next year. The purpose of establishing a research group is discussed as following 4 points.

Therefore, to effectively operate Shelter-in-Place, it is necessary to ensure that it is implemented at the time when radioactive materials are discharged. On the other hand, it is difficult to continue the evacuation for a long period, and it is not a permanent measure, and at some point, a decision must be made to lift the evacuation or switch to evacuation. However, while the Nuclear Emergency Response Guidelines stipulate evacuation and temporary relocation based on radiation dose rates after a release of radioactive materials, they do not indicate the decision to lift the evacuation or switch to evacuation.

1. The shape of the progress of the situation assumed when considering the scope and duration of the indoor evacuation.
2. The scope and duration of indoor evacuation.
3. Continuous period of the implementation of indoor evacuation.
4. Items to be taken into consideration when deciding on the lifting of the shelter-in-place or switching to evacuation/temporary relocation.

The above is an excerpt from Nuclear Regulation Authority (2024.c).

Based on the nuclear emergency response guidelines newly established after post-311, and taking into account the international standards of the International Atomic Energy Agency; IAEA and the lessons learned from the TEPCO's Fukushima Daiichi Nuclear Power Plant accident, the scope of the "Shelter-in-Place" is defined as a nuclear emergency response priority zone, which covers a radius of 5 km to approximately 30 km from nuclear facilities, and provides for emergency evacuation actions and protective measures. The Act also provides for evacuation and protective measures in the event of an emergency. However, considering the damage caused by the Noto Peninsula Earthquake of 2024, as mentioned above, there are serious doubts and concerns about whether this is really feasible in reality. I hope that this meeting of the study team will first deepen discussions on the effective operation of Shelter-in-Place, more concrete ways of indoor evacuation, the accompanying risk communication, and nuclear disaster prevention suitable for the actual conditions of each region. At the present stage, how to lead residents to a safe place in the event of an emergency? It will be necessary to deepen discussions on how and when information should be disseminated, the methods and means of information transmission, and how to improve the information literacy of those who need to evacuate. Looking at the impact of the Noto Peninsula earthquake and the damage report from Hokuriku Electric Power Company, much of the information was reported after the fact, leaving many issues and questions for the future as to how to reliably convey real-time information that would be necessary in an emergency and how to translate that information into evacuation actions. For local governments throughout Japan and residents living in the vicinity of nuclear power facilities, these issues should have been reaffirmed as their own concerns, rather than those of others. Although the Noto Peninsula earthquake and the series of disasters around the Shika NPP did not develop into a serious nuclear disaster in the form of a radiation leak, the study team's discussions on how to protect the lives and property of the people from a possible future nuclear disaster, compound disaster, or other NATECH disaster will be closely focused.

Author Contributions

Conceptualization, K.H. and R.S.; methodology, K.H.; formal analysis, K.H.; investigation, K.H.; writing—original draft preparation, K.H.; writing—review and editing, R.S.; All authors have read and agreed to the published version of the manuscript.

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Conflicts of Interest

The authors declare no conflict of interest.

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