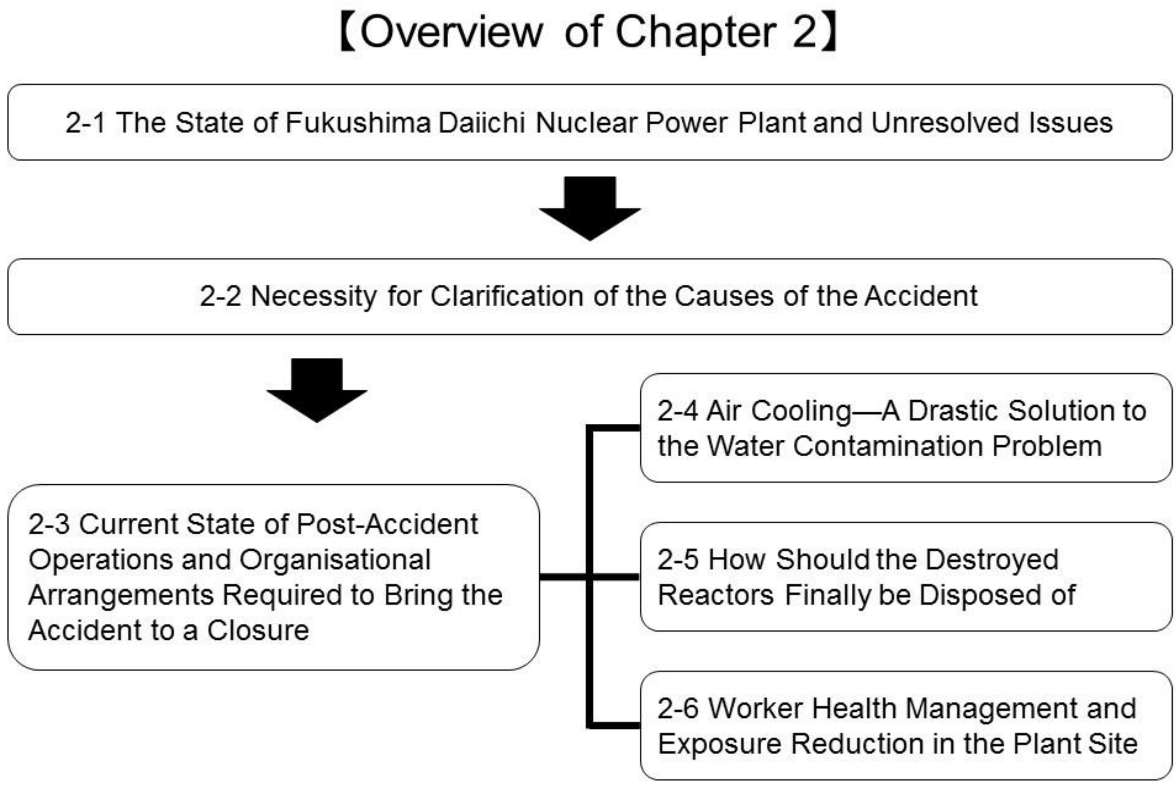
Chapter 2
The Actual State of the Fukushima Daiichi Nuclear Power Plant Reactors and Issues Surrounding the Accident Settlement

2-0 Overview and Structure of Chapter 2

In this chapter, we firstly look chronologically at what took place inside Tokyo Electric Power Company (TEPCO)'s Fukushima Daiichi Nuclear Power Plant, from 11 March 2011 onwards, and through what process the nuclear power plant has passed to reach the current situation. What we must understand is that, even now, an accurate and detailed timeline of the accident has still not been ascertained and continued investigations are vital. The reoccurrence of nuclear power plant accidents cannot be prevented without clarification of the causes of the accident based on thoroughgoing investigations at the accident site. In addition, we analyse the causes and background to the radioactive water problem, which is becoming so complex and severe that it is now a major stumbling block to conclusion of the accident. We then summarise issues and proposals aimed at bringing the accident to an end.

We have once again been reminded of the scale of nuclear disasters, which cannot be reversed once they have occurred, and the subsequent difficulties in bringing these disasters to a close. While three years have now passed since the accident, who could have imagined beforehand that the contaminated water problem, which could be said to be a secondary consideration, is now the greatest barrier blocking the way to a permanent conclusion to the accident? One significant factor that is causing difficulties in bringing the accident to a conclusion is that the responsible organisations have become almost completely dysfunctional. An integrated implementation system in the form of an "Agency for the Decommissioning of the Fukushima Daiichi Nuclear Power Plant (Fukushima Decommissioning Agency–FDA)" should be set up on a state scale as a matter of urgency. At the same time, arrangements should be made for the liquidation of TEPCO.



According to the “Mid-and-Long-Term Roadmap”[143] for the conclusion of the accident issued by the government and TEPCO, a flooding method[144] will be used to remove the molten fuel (debris) over the next 30 to 40 years. There is a strong possibility that this will become little more than an illusory notion, and, furthermore, involve immense worker exposure. Reducing worker exposure by improving the radiation environment at the site, as well as the social and labour environment, are the most serious issues facing the continuation of work to end the accident in the long-term. In technical terms, we propose to resolve the water contamination problem by introducing air cooling of the fuel debris, and simultaneously to minimise worker exposure to radiation by constructing a sarcophagus over the stricken reactors. It would seem that there is little choice but to use this monument, consisting of the destroyed reactors and surrounding area, as a “negative heritage”, a permanent reminder of humanity’s error in attempting to harness the power of the atom. In any case, removal of the fuel debris by the flooding method is a dangerous choice and plans for this approach should be suspended immediately.

[143] Tokyo Electric Power Company Fukushima Daiichi Nuclear Power Plant Decommissioning Measures and Implementation Council, “Mid-and-Long-Term Roadmap towards the Decommissioning of TEPCO’s Fukushima Daiichi Nuclear Power Plant Units 1-4”, [In Japanese], 27 June 2013, http://www.tepco.co.jp/nu/fukushima-np/roadmap/images/ t130627_04-j.pdf

[144] To prevent radioactivity being dispersed into the atmosphere, the containment vessel is filled with water and the molten fuel (debris) is then removed.

Table 2.1 Fukushima Daiichi Nuclear Power Station Accident Timeline

2011 11 Mar.	Actions by government and TEPCO	Unit 1 460MW, Online	Unit 2 784MW, Online	Unit 3 784MW, Online	Unit 4 784MW, Down for maintenance
14:46	M9.0 Tohoku-Pacific Ocean Earthquake occurs				
		Automatic Reactor Scram			
		Loss of external power (Automatic activation of emergency diesel generators)			
15:37		Emergency diesel generators stop due to breakdown. Total loss of AC power. Oil tanks, etc. washed away (Arrival of tsunami)			
16:00	TEPCO notification in accordance with Art.10 of Act on Special Measures Concerning Nuclear Emergency Preparedness				
		High pressure core injection system (HPCI) failure			
		Emergency isolation cooling system (IC) malfunction	Reactor Core Isolation Cooling System (RCIC) starts up		
		Loss of cooling function			
16:45	TEPCO report in accordance with Art.10 of Act on Special Measures Concerning Nuclear Emergency Preparedness				
21:23	PM Kan orders evacuation from area within 3 km radius, and sheltering indoors from 3 km to 10 km radius.				
21:50		Radioactivity level inside building rises			
12 Mar.					
00:06		Preparation for containment vent ordered			
02:30		Pressure in pressure vessel and containment rises to 8 atms. (Pressure vessel damage)			
05:44	Evacuation from area within 10 km radius ordered				
11:36				RCIC stops	
12:35				HPCI starts up	
14:30		Containment vent operation implemented			
15:36		Hydrogen explosion in reactor building			
18:25	Evacuation order altered to 20 km radius				
19:04		Seawater injection to reactor begins			
13 Mar.					
02:42				HPCI stops	
				Loss of cooling function	
08:41				Containment vent operation implemented	
13:12				Seawater injection to reactor begins	
14 Mar.					
04:08					Spent fuel pool (SPF) water temperature rises to 84ºC
05:20				Containment vent operation implemented	
11:01				Reactor building explosion	
13:25			RCIC stops		
			Loss of cooling function		
19:54			Seawater injection to reactor begins		
15 Mar.					
00:01			Containment vent operation implemented		
05:25	Government and TEPCO set up Disaster Management Centre				
06:10			Sound of severe shock heard in vicinity of pressure suppression vessel (Pressure 0 atms.)		
06:14					Explosion in vicinity of SFP
07:00	With the exception of disaster prevention personnel, about 650 workers temporarily evacuate to Fukushima Daini Nuclear Power Station.				
09:38					Fire in reactor building
11:00	Sheltering indoors ordered from 10 km to 20 km radius				
	Ministry of Health, Labour and Welfare raises permissible dose for workers to 250 mSv				
		Inability to cool reactors and SFPs continues			
18 Mar. 17:50	Nuclear and Industrial Safety Agency (NISA) announces accident to be Level 5 on the INES scale				
24 Mar.~		Radioactivity of between 10,000 and 100,000 times more concentrated reactor water detected in water accumulated in the basement of the turbine buildings, indicating that the fuel had sustained severe melting and damage and water had flowed out into the turbine building.			
		Traces of plutonium detected in soil samples taken from within the grounds of Fukushima Daiichi Nuclear Power Station on 21 and 22 March.			

25 Mar. 11:46	Voluntary evacuation requested from 20 km to 30 km radius
5 Apr.	Nuclear Safety Commission advises that the evacuation criteria be a total dose of 20 mSv.
11 Apr.	30 km radius established as planned evacuation area.
12 Apr.	NISA announces accident to be Level 7 on the INES scale
12 May.	TEPCO first admits that Unit 1 experienced meltdown.

Prepared with reference to the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), taking into account facts known later, and by revising the table published in the Citizens' Nuclear Information Center Tsushin No.442, p.6 (April 2011)

As some parts of the progression of the accident are as yet unclear, this table may be reviewed in the light of further evidence becoming available in the future.

2-1 THE STATE OF FUKUSHIMA DAIICHI NUCLEAR POWER PLANT AND UNRESOLVED ISSUES

[DETAILS]

1. The cause of the Fukushima Daiichi Nuclear Power Plant accident was failure by the government and TEPCO to make adequate provision against an accident, including prior assessments of massive earthquakes and tsunamis.[145] Further, as the disaster-prevention system almost completely failed to function after the outbreak of the accident, the number of exposed residents and the degree of exposure were unnecessarily increased.
2. This accident has made it clear that once a serious accident occurs at a nuclear power facility it cannot be controlled by human technology. The government's "declaration of a cold shutdown state" (16 December 2011) was totally unfounded in fact. The accident is still continuing to this day. Workers at the site are being forced to struggle with the cleanup operations in an exceedingly severe environment.
3. Due to the high level of radioactive contamination, it is almost impossible to carry out onsite inspections of Fukushima Daiichi Nuclear Power Plant's important equipment. This causes difficulty in assessing the state of the damage and the causes of the accident. It is therefore impossible to obtain the information and knowledge necessary for preventing reoccurrences of accidents. It is also impossible to gather basic information, such as the flow route of groundwater into and the flow route of contaminated water out of buildings, that is absolutely necessary for designing countermeasures. These are difficulties that are inescapably associated with severe nuclear power plant accidents and are symbolic of the dangers of nuclear power plants when compared with other industrial technologies, which have been improved in response to repeated accidents and other mistakes.

[DETAILS]

2-1-1 What happened in the Fukushima Daiichi Nuclear Power Plant accident?

When the M9.0 earthquake hit Fukushima Daiichi Nuclear Power Plant, Units 1, 2 and 3 were online at rated capacity, Unit 4 was under repairs to the inside of the reactor, and Units 5 and 6 were down for regular maintenance. The control rods automatically inserted in the reactors that were online, bringing the fission reaction to an emergency halt. A huge tsunami struck Fukushima Daiichi Nuclear Power Plant about 50 minutes after[146] the occurrence of the earthquake.

Although the fission chain reaction was halted in the online Units 1, 2 and 3, the fission products of uranium that had accumulated during operation continued to release large amounts of decay heat. The normal external power (AC), the emergency diesel power supply (AC), and batteries (DC power supply) had all failed due to the earthquake and tsunami, the emergency core cooling system (ECCS)[147] function had been lost, so the

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[145] In 2006, the concept of "residual risk" (the potential for damage to the reactor core by an earthquake that exceeds the reference seismic movement) was introduced at the time of the revision of the Regulatory Guide for Reviewing Seismic Designs of Nuclear Power Reactor Facilities. Despite the fact that it is scientifically impossible to determine the greatest reference seismic movement and reference tsunami for use in design, nuclear power plants cannot be designed unless the reference seismic movement and reference tsunami are established for each site. Although the "residual risk" was introduced with the awareness of this contradiction, that awareness was not put to use when determining design criteria. See Section 4-1 for "safety thinking" in regulatory criteria for nuclear power facilities. See Section 4-4 for "residual risk".

[146] There are uncertain factors involved in the time of arrival of the tsunami, and these are important clues for uncovering the true causes of the accident (see the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), Section 2.2.3.4).

[147] The Unit 1 IC (isolation condenser) and the Units 2, 3 and 4 RCIC (reactor core isolation cooling system) are not classified as the ECCS.

reactor core fuel rods overheated and melted down. It is possible that in Unit 1 piping was ruptured or damaged by the earthquake and that the core meltdown was accelerated by a loss of coolant accident (LOCA). TEPCO has stated that the zirconium alloy used in the fuel rod cladding tubes and channel boxes reacted with steam to produce large amounts of hydrogen gas, which exploded inside the reactor buildings of Units 1 and 3, blowing away the walls and ceilings. TEPCO has also said that hydrogen gas exploded in the Unit 4 reactor building after flowing into Unit 4 through piping from Unit 3.[148] In Unit 2, the reactor building blowout panel had already been blown out by the shock of the explosion in Unit 1, so there was no explosion leading to a collapse of the building there.[149]

2-1-2 Continuing problems at Fukushima Daiichi Nuclear Power Plant

In the process of the series of accidents, the confinement function of the containment vessel was lost, resulting in releases of large amounts of radioactive materials into the environment.[150] Even now, although far less compared with the time of the accident, releases of radioactive materials are continuing all the time.[151] In addition, as mentioned below, far greater amounts of radioactive materials are flowing into the sea.

Cooling water is being supplied to the molten nuclear fuel in Units 1, 2 and 3 through a makeshift circulation system. The cooling water is constantly leaking out returned via a route from the reactor to the reactor containment vessel and then to the reactor building, where the accumulated contaminated water is pumped up and supplied to the reactor after removal of radioactive materials such as caesium by use of makeshift treatment equipment. The contaminated water is flowing into the turbine building as well as the reactor building, though the route is not clear. As the underground walls and floors of both buildings are constructed of reinforced concrete and are not watertight, groundwater is flowing in at the rate of around 400 tons per day. The contaminated water level in the buildings is controlled to be lower than that of the external groundwater to prevent contaminated water from leaking out. Contaminated water has also accumulated in the trenches that connect the two buildings. Since the amount of contaminated water continues to increase every day, large numbers of temporary storage tanks are being set up on the premises of the nuclear power plant, but eventually there will be no more space on which to set up new tanks. The trenches mentioned above are also not watertight and many of the temporary storage tanks, which were constructed in great haste from flanged parts held together by nuts and bolts, have become a huge problem because of frequent leakages of contaminated water. In particular, it has become clear that leaks from the trenches have continued since the occurrence of the accident, and this is developing into an international issue.

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148 Regarding the explosion in the Unit 3 reactor building, according to one theory, cooling of the spent fuel stored in the spent fuel pool on the fifth floor had stopped, and while the water in the pool was boiling the hydrogen explosion that occurred in the upper part of the of the building may have triggered a nuclear explosion. However, since too little information has been disclosed by TEPCO, such as underwater photographs of the fuel pool, there is insufficient proof of such an event. Whatever the case may be, it is thought that a hydrogen explosion occurred.

149 As the pressure in the Unit 2 pressure suppression chamber dropped rapidly at the same time as this explosion in Unit 4, it was said at first that an explosion had occurred in the vicinity of the Unit 2 pressure suppression chamber. However, later, the sound of the explosion was thought to be from Unit 4, and it has not been confirmed that an explosion occurred inside Unit 2. But as the amounts of radioactive materials released from Unit 2 are relatively high, there is a strong possibility that the containment or surrounding piping has been badly damaged.

150 There are several possibilities for the routes by which radioactive materials leaked from the buildings, including: through the vent line, opened for venting operations; through flanges and cable holes in the containment vessel, which had been damaged by high temperature and pressure; or from damaged parts such as ruptures and cracks in boundary piping. This possibility is especially strong in Unit 2, where venting failed. TEPCO claims that venting of Units 1 and 3 was successful, but since disassembling checks have not been carried out on the rupture disks (a safety valve which ruptures under high pressure), it is unclear whether they have actually ruptured or not. If the rupture disks have not ruptured, then, as with Unit 2, radioactive substances have leaked out through another route.

151 According to a TEPCO announcement in February 2014, this was 10 million Bq per hour. Releases fluctuate and are sometimes observed to become temporarily greater.

Coming into 2014, contamination consisting of strontium and other elements was detected at the highest level since the accident in a well between the turbine building and the sea, and it was confirmed that water contaminated with high levels of radiation is flowing into the sea via the groundwater. Consideration of measures to stem the flow of contaminated water into the sea is continuing. Ideas such as a frozen earth barrier method have been mooted, but the search is still on for a workable proposal.

In order to reduce the increasing volumes of contaminated water that need to be stored in the temporary storage tanks, consideration has begun on changing the method of cooling the molten nuclear fuel from the current "water-cooling method" to an "air-cooling method", but since the location, form and so on of the nuclear fuel is as yet unclear, the specific plan is still in the preparation stage (see Section 2-4).

A multi-nuclide removal system (ALPS—Advanced Liquid Processing System), which is supposed to be capable of removing all nuclides except tritium, has been installed to treat the large amount of contaminated water that has accumulated in the temporary storage tanks, but performance of the equipment in test runs has not gone well, and it is not yet officially operative.

The spent fuel pools (SFP) of each unit continue to be cooled by makeshift cooling systems. All the reactor core fuel of Unit 4 had been moved into its SFP because repairs were being carried out inside the reactor, so the pool contained 1,535 fuel assemblies (of which 204 were fresh fuel). Located in the highest part of the reactor building, which had almost collapsed, the SFP was damaged in a subsequent earthquake. Since there was the concern that huge releases of radioactive materials far exceeding those of March 2011 might occur if it became impossible to cool the fuel, the underside of the pool was fitted with steel supports. This was also an emergency measure, and operations to transfer the fuel stored in the Unit 4 SFP to an interim storage facility onsite began in November 2013. It was expected that the transfer of all the fuel would require about a year, but there were anxieties about the possibility of an accident if a large earthquake struck the site during the transfer operation. No earthquake-proofing reinforcements were carried out for Units 1, 2 and 3. [Update at the time of translation: Transfer of the fuel assemblies from Unit 4 to the common pool was completed in December 2014. The outlook is obscure as to when and how the spent fuel rods in the upper floor SFPs of Unit 1, 2 and 3 can be transferred.]

As a sufficiently high seawall has not been constructed even after the March 2011 tsunami, the Fukushima Daiichi Nuclear Power Plant site overall is still vulnerable to tsunami events. If there are strong aftershocks, perhaps causing a further tsunami to hit the site, there is the fear that the hoses and other equipment involved in the makeshift cooling water circulation could easily be damaged, or even washed away. Or if a strong aftershock were to hit the reactor buildings, where the spent fuel is stored in the SFPs, there is the fear that the pools might develop fissures from which the water would drain out, making it impossible to cool the fuel or shield the radiation from inside the pool. [Update at the time of translation: Although most of the soft hoses have since been replaced by metal or hard-plastic pipes, strong aftershocks remain grave concerns.]

In Section 2-3 we give proposals for means and measures that should be taken at the Fukushima Daiichi Nuclear Power Plant site. We also discuss the problem of radiation protection and health management of exposed workers in Section 2-6.

2-1-3 What has not been investigated about the Fukushima Daiichi Nuclear Power Plant accident

The detailed state of the interior of the buildings is almost completely unknown. This is because particularly important aspects of the situation inside the nuclear power plant, for instance the location and state of the molten nuclear fuel (debris), the reactor pressure boundary[152], the reactor containment vessel boundary, the state of damage to the ECCS-related equipment, piping, etc., cannot be directly inspected, as excessively strong radiation precludes approach to the sites by people. The destructive forces may have included earthquakes, tsunamis, hydrogen explosions, high temperature, high pressure, sloshing (the violent movement of liquids) and so on, but it has not been clarified which of these was responsible for causing each particular kind of damage. This has therefore been an obstacle to understanding the developmental process of the accident. Determining whether the Unit 1 hydrogen explosion occurred on the 5th floor of the reactor building (as explained by TEPCO) or on the 4th floor (as speculated by the NAIIC in the course of its investigations) is extremely important information that has a bearing on whether or not main piping damage was caused by the earthquake. However, despite the fact that it is possible to visit the location, TEPCO blocked an onsite investigation by refusing to cooperate, so confirmation of the facts remains impossible. [Update at the time of translation: In February 2015, onsite inspection of the 4th floor of Unit 1 was finally conducted by a team of expert engineers commissioned by the Governor of Niigata Prefecture, which hosts another TEPCO nuclear power plant now facing the question of whether the reactors will be allowed to restart or not. Former NAIIC member Mitsuhiko Tanaka was a member of the team. The report of this investigation is yet to appear.]

Furthermore, it is still impossible to confirm exceedingly basic aspects of the urgent contaminated water issue. These include, for instance, the contaminated water leakage route from the reactor containment vessel to the below-ground section of the reactor building (i.e., the state of damage to the containment vessel); the inflow route of groundwater to the reactor building (i.e., the state of damage caused by the earthquake to the walls and floors in the below-ground section of the building); and the leakage route from the reactor building to the below-ground section of the turbine building and trenches, and the state of damage in these.

In sum, it is still not possible to obtain the necessary information to assess the true state of the accident, to clarify causes, to prevent reoccurrences, to organise countermeasures for ongoing problems, and to prepare plans for a cleanup of the accident-stricken reactors.

2-2 Necessity for Clarification of the Causes of the Accident

[Details]

1. Clarification of the causes and progression of the accident, as well as continued investigations for those purposes, are absolutely necessary. These investigations are fraught with difficulties and it is expected that they will take many years to complete, so an organisational system and upgrading of laws aimed at achieving this should be implemented without delay.
2. The authorities should carry out a thorough investigation of the criminal liability of people related to the occurrence of the accident, including executives of TEPCO.
3. It is hoped that journalism will contribute to a clarification of the causes of the accident through original research and reportage.

[152] The nuclear reactor pressure boundary consists of the reactor pressure vessel, the reactor cooling system piping, isolation valves, and so on. In a BWR, this is the boundary of the area in which a pressure of 70 atmospheres is maintained. If this collapses, it may lead to a loss of reactor coolant.

[DETAILS]

2-2-1 An organisational system and upgrading of laws are necessary to achieve a thorough investigation

The restart of nuclear reactors is out of the question unless a thorough investigation is performed, but the continuation of investigations into the accident is indispensable even if restarts are not actually implemented. Information obtained from investigations is also necessary to secure the safety of the nuclear power plants that are currently shut down. This information could also be of great use for people associated with the nuclear power business overseas, not only for nuclear power plant accident prevention but also, for example, for nuclear power policy decision-making. This would be an "international contribution" that would make good use of the "negative heritage".

It is vital to preserve the site and the evidence in order to implement this kind of objective and scientific investigation. The permanent loss of important evidence due to the rough-and-ready implementation of the "Mid-and-Long-term Roadmap" must be avoided, if at all possible. For this to happen, laws should be enacted to ensure that the current state of the accident site is not negligently altered, that documentary evidence and other related materials are not destroyed, hidden or lost, and that free access is possible to the site and related materials by empowered investigative organisations.

Both the National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC) and the government's Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company emphasised the necessity for continued investigation of the causes of the accident.[153] A specialist investigative body should be established to systematically preserve the materials and testimony amassed by the accident investigation committees and others, and to continue and develop the investigation based on their outcomes.[154] Avoiding possible "conflicts of interest" in the selection of personnel for such an investigative body would also be indispensable.

Transparency is crucial in the investigation of the causes. In principle, hearings with related people should be held in public and the documentary records published at regular intervals.

An overview of Japan's accident investigation system reveals that the Ministry of Land, Infrastructure, Transport and Tourism (MLIT) has an extra-ministerial bureau, the Japan Transport Safety Board (JTSB) which oversees aircraft, ship and train accidents. The work of the JTSB is to initiate investigative activities immediately after an accident occurs, clarify the causes, make recommendations for preventing the reoccurrence of similar accidents and give opinions (Act for Establishment of the Japan Transport Safety Board, Chapter III "Investigation of Accidents", etc., and Chapter IV "Recommendations and Statement of Opinions"). In the case of fires, at the same time as carrying out fire extinguishing activities, the fire authorities are to begin investigations concerning the causes and damage (Fire Service Act, Chapter VII "Investigation of Fire"). New safety measures are then taken on the basis of the outcomes of these investigations.

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[153] National Diet of Japan Fukushima Nuclear Accident Independent Investigation Commission (NAIIC), (2012) *Report*,. [In Japanese], p.23; Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company (Government Committee), (2012), *Final Report*,. [In Japanese], p.429.

[154] One proposal would be to set up a secretariat in the National Diet Library to collate and preserve documents and records, and manage these together with the materials from the Investigation Committee on the Accident at the Fukushima Nuclear Power Plants of Tokyo Electric Power Company (Government Committee) (currently managed by the Nuclear Regulation Authority (NRA)).

In the case of nuclear power plant accidents, the Law for the Regulations of Nuclear Source Material, Nuclear Fuel Material and Reactors[155] provides for Nuclear Regulation Authority (NRA) officials and others to enter and inspect the facilities and offices, to gain access to documents and so on, and recognises the right of officials to interrogate related persons (Article 68, etc. of the above-mentioned law).

It should go without saying, however, that the clarification of the causes of the Fukushima Daiichi Nuclear Power Plant accident requires the establishment of a separate and powerful body and upgrading of laws for that purpose. That is why we propose the establishment of a specialist investigative body based on the enactment of a new law.

2-2-2 Incomprehensible sluggishness on the part of the investigative authorities

If there is suspicion that an accident has been brought about knowingly or by negligence, the police and prosecuting authorities initiate an investigation. Investigators visit the site and related locations and take statements from related persons. If necessary, a criminal investigation, including searches, confiscation of documentary evidence and the arrest of suspects may be instigated on the basis of warrants (Code of Criminal Procedure, Part II, Chapter I “Inquiry and Investigation”). The purpose of the investigation is limited to building a case on the alleged facts and the establishment of the facts for prosecution, but many of the facts that are brought to light during the process from investigation to prosecution to public trial and verdict are useful for clarifying the causes of the accident.[156]

When considering a possible criminal investigation of the Fukushima Daiichi Nuclear Power Plant accident, there is an extremely strong suspicion that several acts of negligence committed by the company in question, TEPCO, and others were connected to the causes of the accident.[157] In the case of large and small accidents involving death or injury that occur in transport, construction sites or factories, it is commonplace for investigative officials to proceed immediately to the site to impound evidence and arrest suspects. For a massive accident such as that at Fukushima Daiichi Nuclear Power Plant, why the moves by investigative authorities were so abnormally sluggish is beyond comprehension. In cases such as the train derailment accident on the JR West Japan Fukuchiyama Line[158] or the accident involving death and injury of spectators at the Akashi fireworks display[159], top executives of the company or persons responsible for security were prosecuted. They were subsequently proven innocent, but the details of the cases were brought to light before the citizenry through the public trials. The pursuance of criminal liability in the Fukushima Daiichi Nuclear Power Plant accident would also be of use in eliminating moral hazards and preventing reoccurrences of accidents.

2-2-3 Social responsibility of journalism

Lastly, journalism has a crucial role if the investigation of the causes of the Fukushima nuclear power plant

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[155] A law that regulates nuclear source materials, nuclear fuel materials and nuclear reactors.

[156] However, it is also very possible that clarification of the causes of an accident may be hindered by an investigation of criminal prosecution; for instance, when related persons refuse to give testimony at an accident investigation commission for reasons of possible criminal prosecution. Legislative measures are necessary to deal with such problems.

[157] For instance, NAIIC Report, Chapter 1 “Was the accident preventable?”, pp. 57-125.

[158] The accident, in which 107 died and several hundred were injured, occurred on 25 April 2005. In March 2010, three successive CEOs of JR West Japan were indicted for causing death and bodily harm through professional negligence by decision of the committee for the inquest of prosecution, but a not guilty verdict was handed down by the Kobe District Court in January 2012. The not guilty verdict was affirmed when the prosecutor’s office declined to appeal.

[159] The accident, in which 11 died and 247 were injured (according to the Akashi Citizens Summer Festival Accident Investigation Committee), occurred on 21 July 2001. A former Akashi Police Vice Superintendent was indicted for causing death and bodily harm through professional negligence by decision of the committee for the inquest of prosecution, but a not guilty verdict was handed down by the Kobe District Court. The appeal court decision is expected on 23 April, 2014. [Update at the time of translation: On 23 April 2014, the Osaka High Court upheld the Kobe District Court ruling. The appeal is due to be heard in the Supreme Court.]

accident is to be carried out appropriately and assist in preventing reoccurrences of nuclear power plant accidents. In order to report the important facts, it is necessary to bring pressure to bear for a removal of the veils of secrecy that surround the state and companies. There may be times when the site must be visited, despite the dangers. It is also very possible that one might be arrested and indicted on a charge of disclosure of secrets[160], face a claim for damages from a company[161] or be exposed to radiation.

There have been many excellent press reports and programmes that have cut through to the core of the issues, but at the same time there have also been tedious articles that simply pass on the explanations of the government and TEPCO uncritically. There have also been inaccurate reports, probably based on inadequate knowledge, as well as reports that did not show an adequate understanding of the intention of the informant. In the period immediately after the accident on 11 March 2011, Japanese media company journalists, with a few exceptions, avoided visiting the area around the accident site, and failed to meet the expectations of readers and viewers, merely presenting reportage based on official announcements of the government and TEPCO. Those who dared to face the dangers in the aftermath of the accident and attempted to gather material at the accident site were mainly free journalists. Nevertheless, it is well known, since it later became an issue, that when the government and TEPCO first allowed reporters into the grounds of the stricken power plant, free journalists not affiliated to the press club were shut out. We would like to reemphasise here the social responsibility of journalism.[162]

2-3 Current State of Post-Accident Operations and Organisational Arrangements Required to Bring the Accident to a Closure

[DETAILS]

1. While the contaminated water problem has been recognised as the greatest obstacle in the accident cleanup operations at Fukushima Daiichi Nuclear Power Plant over the past three years, countermeasures have all met with miserable failure. Clearly the related organisations have fallen into dysfunction and lack effective methods for getting the job done.
2. Once bankruptcy procedures for TEPCO have been carried out, the Nuclear Damage Compensation and Decommissioning Facilitation Corporation established by the government, and the Fukushima Daiichi Decontamination and Decommissioning Engineering Company, established as a subsidiary within TEPCO, should be amalgamated to form an “Agency for the Decommissioning of the Fukushima Daiichi Nuclear Power Plant (Fukushima Decommissioning Agency–FDA)” that would push forward all decommissioning work in an integrated manner as an independent entity both in terms of organisation and finances.

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[160] For instance, the reporting of the secret treaty on Okinawa by the Mainichi Shimbun reporter Takichi Nishiyama. Nishiyama was arrested, indicted and pronounced not guilty in the first instance, but a guilty verdict was handed down by the Supreme Court in 1978.

[161] A so-called SLAPP (Strategic Lawsuit Against Public Participation) suit. For instance, when the Shakai Shinpo (official organ of the Social Democratic Party of Japan) reporter Minoru Tanaka wrote an article about the nuclear power interests of a security company CEO in the *Shukan Kinyobi* magazine (16 December 2011 issue) he received a claim for damages of 67 million yen. The CEO later withdrew the claim for reasons that are unclear.

[162] For treatments of reportage on the Fukushima Daiichi Nuclear Power Plant accident, see, for example, the November 2011 issue of “The Tsukuru”; [In Japanese]; the April extra issue of “Days Japan” [In Japanese], published on 9 March 2012; the June and July 2012 issues of “Journalism” [In Japanese]; the January 2013 issue of “Gakujutsu no Doko (Academic Trends),” [In Japanese], and others.

[DETAILS]

2-3-1 Current state of the Fukushima Daiichi Nuclear Power Plant accident site

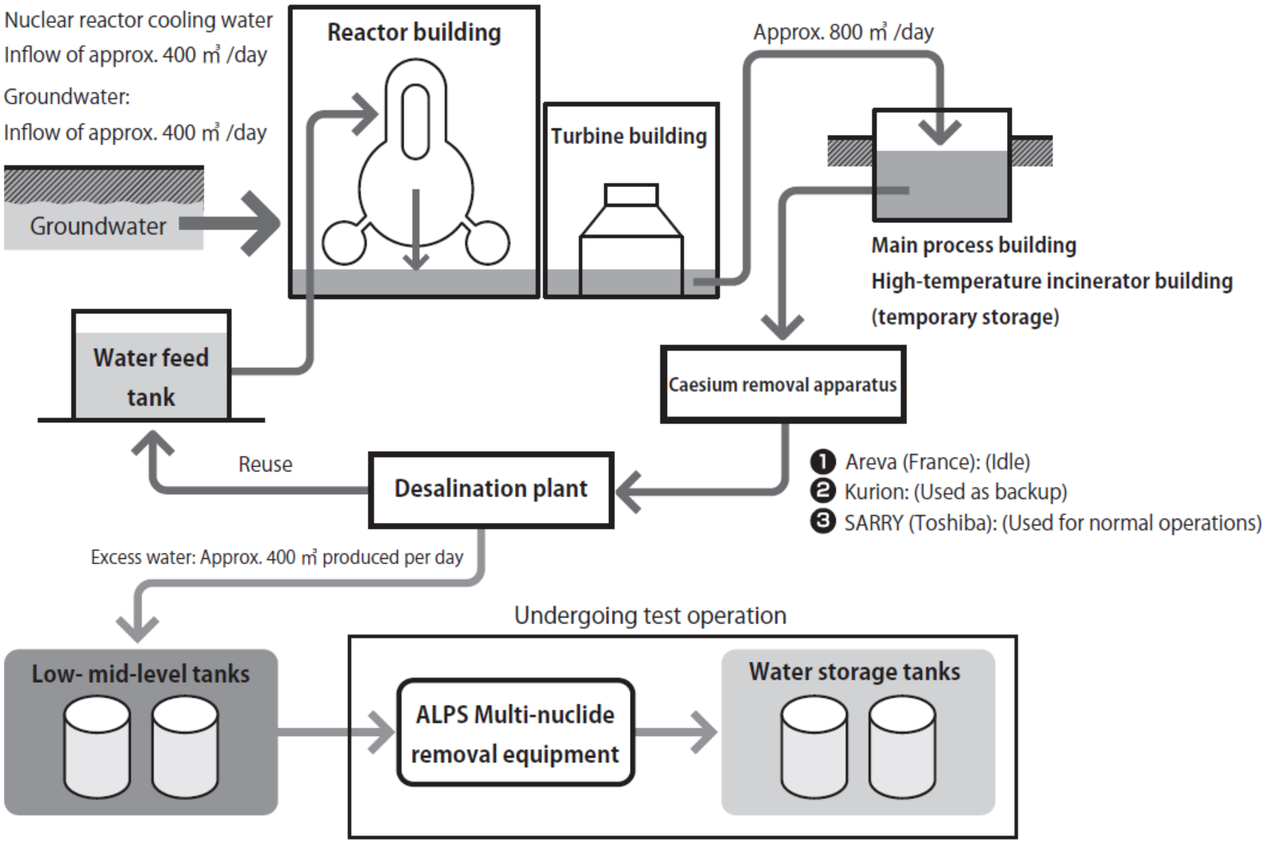
At the time of writing this *Policy Outline* (late March 2014), despite the passing of three years since the accident, releases of radioactive materials and stored contaminated water to the ocean from the Fukushima Daiichi Nuclear Power Plant site have been occurring incessantly. While releases of stored water have been substantially reduced, the outflow of radioactive materials via the groundwater is still continuing, High concentrations of caesium and strontium have been continually detected in observation wells that have been sunk in a number of locations, and incidents involving the leakage of around 300 tons of stored contaminated water in August 2013 and around 100 tons in February 2014 are still fresh in our memories. The former is the equivalent of an INES Level 3 serious incident. It must, therefore, be said that the statement by Prime Minister Abe in September 2013 during a speech inviting the Olympic Games to Tokyo that "the contaminated water is under control" showed a great lack of thoughtfulness and awareness of the current situation. [Update at the time of translation: Whereas the frequency of leakages from the water tanks is becoming somewhat lower, and bolt-fastened tanks are being replaced by welded tanks that are less vulnerable to leakage, the outflow of radioactive materials via the groundwater flow is still continuing. In February 2015, it was revealed that TEPCO had knowingly abandoned, for nearly a year without reporting to NRA, a flow of highly contaminated rainwater from the roof of the Unit 2 reactor building into the sea via a drainage channel which leads to the sea outside the power plant harbour wall. TEPCO and the government had repeatedly claimed that the outflow of contaminated water was confined to the harbour. As a matter of fact, the situation is out of control and deteriorating.]

In this situation, the existence of radioactive contaminated materials dispersed around the site—such as highly concentrated contaminated water still retained in trenches beneath the buildings and elsewhere, excess contaminated water deriving from the mixture of the reactor core cooling water and inflowing groundwater, equipment, various kinds of debris, and soil—has become the greatest obstacle to the cleanup and decommissioning project at Fukushima Daiichi Nuclear Power Plant. Nevertheless, in the three years since the accident neither the government nor TEPCO has taken any far-reaching measures to prevent contamination of the ocean, which continues to worsen. The deterioration of the contaminated water problem has been a direct result of failures by TEPCO, but more fundamentally the government has not given serious attention to the issue. This originates in a failure to establish responsible cleanup management institutions through policy means. One example is that while government-related persons were aware in the period soon after the accident of the necessity for an underground water barrier as a countermeasure to increases in contaminated water, the implementation of this measure was not demanded.[163] Rather, contrary to the slogan "government in the forefront", no effective measure was taken and the matter was simply left in the hands of TEPCO. This is one factor that has brought about the dismal state of affairs that exists today.

[163] Mabuchi S. (2013), *The Realism of Nuclear Power Plants and Politics.* [In Japanese] Tokyo: Shinchosha, p.104.

Figure 2.1 Flow of contaminated water countermeasures

(Note：Flow rates indicated are as of March 2014. Prepared from TEPCO materials.)



Since May 2011, TEPCO has announced the release to the ocean of 20 trillion Bq of caesium 137 and 10 trillion Bq of strontium.[164] With ocean contamination worsening, the resumption of fishing along the Fukushima coastline is still delayed. According to a 25 February 2014 TEPCO report, the total amount of contaminated water stored onsite at the Fukushima Daiichi Nuclear Power Plant had reached 520,000 tons, of which 90,000 tons had accumulated in the basement of the reactor and turbine buildings and 430,000 tons was stored in tanks.[165] Moreover, 400 tons of excess contaminated water continue to be generated each day (**Figure 2.1**). Even if this contaminated water is treated in the ALPS multi-nuclide removal equipment, tritium cannot be removed, so it is necessary to continue to store the water in tanks. [Update at the time of translation: As of 19 February 2015 (TEPCO press release), the total amount of contaminated water had reached 609,000 tons, only 51.6 % of which had been treated using the ALPS equipment. The total storage capacity onsite is 781,000 tons. Water accumulation in the reactor/turbine buildings of Unit 1, 2, 3 and 4 is thought to total around 63,900 tons.]

2-3-2 Factors causing deterioration of the problems and their background

Power companies are a type of process industry. The nature of their work is such that it can be formulated in detailed and standardised manuals, be they for operating the plant, purchasing equipment or construction / maintenance work. This nuclear power plant accident and the work to bring it to a conclusion, however, pose a huge and highly irregular form of work that is so extraordinary that a person might only experience something like it once in his or her lifetime. People engaged in this work always meet unknown problems

164 TEPCO press handout material of 21August 2013 titles "Assessment of Outflow Amounts of Radioactive Materials". Further, the Japan Atomic Energy Agency (JAEA) has estimated the releases to the sea from immediately after the accident to the end of April 2011, including those occurring via the atmosphere, at 3,600 trillion Bq for caesium alone.

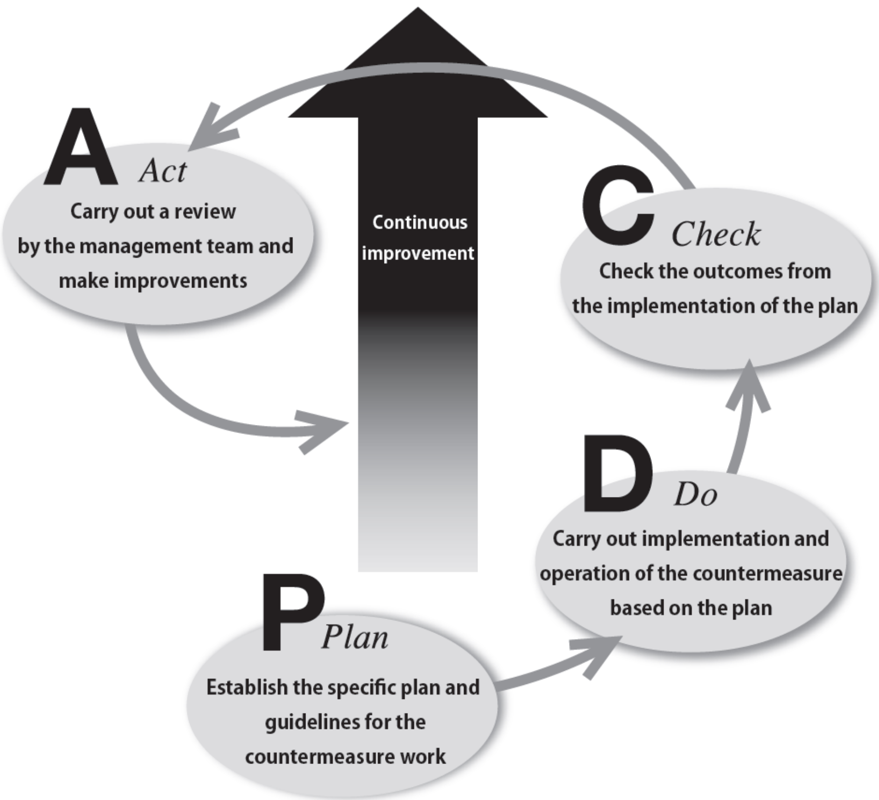
165 TEPCO press release of 26 February 2014, titled "Storage of Accumulated Water and Treatment Situation Report No.139".

and have to make decisions about them at very short notice. This is very different from the normal pattern of work in a power company, and a kind of work that they are not good at. In addition, TEPCO is having to aim at two conflicting targets, one dealing with the accident and the other with business recovery. It may be surmised that TEPCO has fallen into a state where both the organisation and management have become unable to cope with the problems that are arising. As a result, even though the work to bring the accident to an end, including the measures against contaminated water, is defective, TEPCO is making moves to improve company performance by attempting to forcibly restart Kashiwazaki-Kariwa Nuclear Power Plant. The root of the problem lies not simply in the motivational aspects of related personnel, but in the fact that the business management target is split and the organisation has fallen into a dysfunctional state. TEPCO work sites continue to drift along without a clear vision.

Moreover, TEPCO has for some time suffered from ‘big company disease’ in the form of organisational fatigue, lack of transparency, a stuffy and bureaucratic atmosphere, weakness of individual decision-making power, and lack of technical ability due to an unhealthy dependency on suppliers and partner companies. As if that were not enough, in-house motivation has fallen to an exceedingly low level due to critical public opinion arising from repeated bungling and cover-ups in the accident cleanup operations.

Nevertheless, even though that may be the case, it does not entitle TEPCO to cite these problems as excuses for the expansion and failure of the contaminated water problem. In particular, TEPCO’s sloppiness over the contaminated water countermeasures should be roundly criticised from the perspective of quality management (QM). For instance, with regard to the design and installation of the contaminated water tanks, the following problems were conspicuous: problems with bolt tightening that made leaking of the aging and decrepit tanks inevitable; the fact that water level indicators and alarm units were not installed on each of the tanks; insufficient height of flood prevention dikes; failure to install venting equipment; disregard for ground tilt; and so on. Furthermore, there has been little sign of improvement even after the faults were recognised, and tanks of similar design have continued to be installed. Essentially, this indicates a collapse or complete lack of a quality management system (QMS) capable of improving technical or organisational defects through the functioning of a PDCA (Plan-Do-Check-Act) cycle (see **Figure 2.2**). Reoccurrences of the problems cannot be avoided without a revival of the QMS function.

Figure 2.2 Diagram of the PDCA cycle (ISO9001)

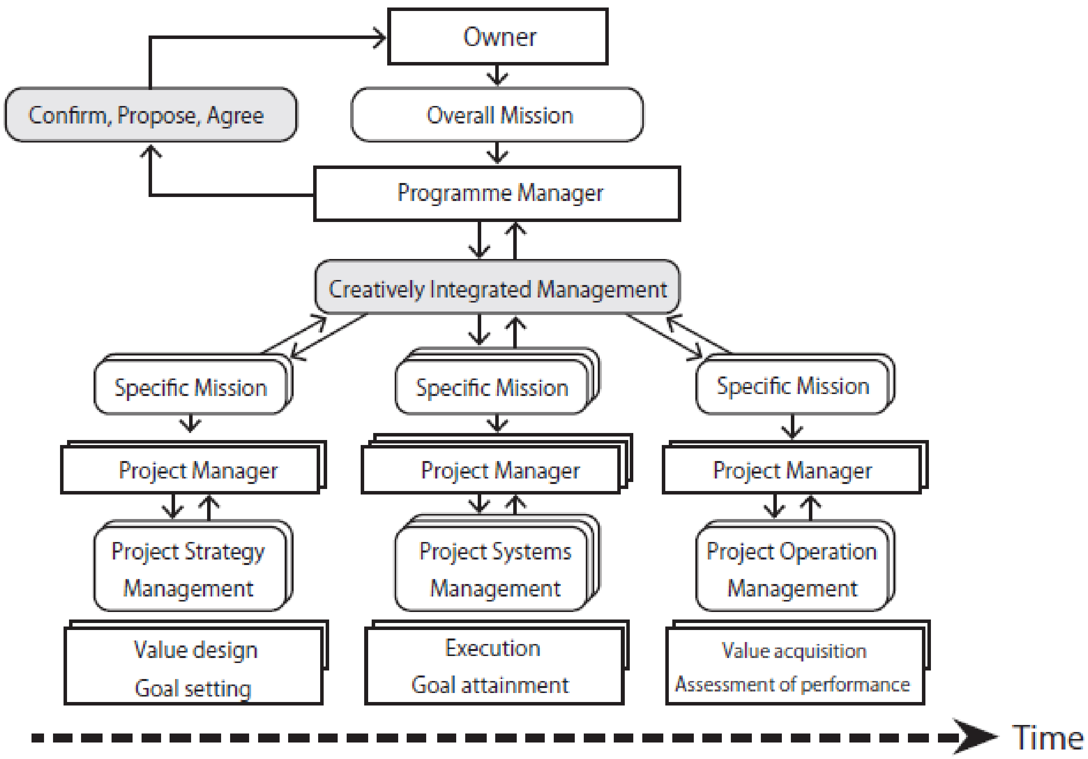


Quite belatedly, on 26 August 2013 TEPCO set up a "Contaminated Water and Tank Headquarters". Because the TEPCO CEO doubles as its head, and because it is situated beneath the board of directors, this organisation is also subject to corporate logic. It will therefore not resolve the various organisational problems mentioned above.

2-3-3 What should the organisational structure look like?

Firstly, focussing on the contaminated water countermeasures, the body that deals directly with the accident cleanup should be independent both organisationally and financially. This is a premise for agile management to optimise the plan for bringing the accident to a conclusion. In April 2014, the government established the Nuclear Damage Compensation and Decommissioning Facilitation Corporation by adding the decommissioning function to the previous organisation, and at the same time the Fukushima Daiichi Decontamination and Decommissioning Engineering Company was established as a subsidiary within TEPCO. The former is supposed to give instructions to the latter, but this is a half-baked reform with little hope of bringing about a radical resolution to the problems arising from organisational problems mentioned in the previous section. The overall premise should be to set up a "Fukushima Decommissioning Agency (FDA)" to push forward with all the work of decommissioning on an integrated basis by amalgamating the Decommissioning Facilitation Corporation and the Fukushima Daiichi Decontamination and Decommissioning Engineering Company through a fundamental review of organisational aspects, and on the premise of TEPCO bankruptcy proceedings being carried forward. In addition, massive costs are involved in the decommissioning and cleanup work and it will be necessary to request the public to bear the burden after TEPCO bankruptcy proceedings have been taken (see Section 5-4). If that is the case, it is more necessary than ever to proceed steadily with the work of bringing the accident to a conclusion while, at the same time, securing transparency and striving to minimise the cost burden.

Figure 2.3 Programme management concept



(Prepared based on the concept of P2M version 2.0 by the International Project Program Association)

Based on this premise, a Program Management Office (PMO) with the special function of bringing the accident to a close should be formed and given wide-ranging powers, including formulation and execution of a budget. Programme management is a means of integrated management that is positioned above a group of several projects, and which provides the basis for success of each project, such as through resource allocation, and so on (see **Figure 2.3**). For the realisation of the PMO, it would be necessary to rely on the dispatch of task-oriented human resources, including those with experience of overseas mega-projects, from a number of companies with a broad focus on engineering. It would be especially welcome if manufacturers and general construction technical staff that have previously had deep relations with the nuclear power industry would participate in the PMO, after having first divested themselves of vested interests and severed links with the so-called "nuclear village". It may also be necessary to request the participation of experienced overseas engineers. Only a state-scale "Fukushima Decommissioning Agency (FDA)" would be able to perform organisation building of this nature.

2-4 Air Cooling—A Drastic Solution to the Water Contamination Problem

[Details]

1. We propose a shift from water cooling of the molten fuel debris to air cooling as a means to fundamentally resolve the contaminated water problem. This would be conditional on the decay heat decreasing to a level where it is possible to remove it by air cooling, but we anticipate that there is a strong probability that this can be achieved.
2. The following two contaminated water countermeasures should be implemented as a matter of urgency: 1) expansion of water storage capacity through the construction of large-scale 100,000-ton-class tanks;

2) construction of a barrier and appropriate use of paving or coating[166] to prevent the inflow of groundwater and surface water into the contaminated site.

[DETAILS]

2-4-1 Mechanism of the formation of contaminated water and the significance of air cooling

As stated in a previous section (2-3-1), the radioactive water problem arises when the drained cooling water, already highly contaminated through its contact with molten fuel debris, intermingles with inflowing groundwater (refer to **Figure 2.1**). Each day, 400 tons of excess water will continue to be formed unless the inflow of groundwater is suppressed. The circulating water will also continue to be contaminated with radioactivity as long as water is used to cool the fuel debris. TEPCO is currently making efforts to block or suppress groundwater inflow by constructing a barrier. However, the frozen earth barrier method that has been chosen is still at a stage where the results of repeated experiments are being reflected in the design, and there is still uncertainty about how effective it will be. It is possible that this research effort will end in failure after incurring huge costs in terms of both funds and time.

Meanwhile, an approximate calculation of debris decay heat based on injected water and temperature data as of 6 February 2014 has been published by TEPCO: [167]

Unit 1: 60 kW
Unit 2: 120 kW
Unit 3: 120 kW

We believe these values are of a calorific and temperature level at which the fuel debris itself and the steel vessels, concrete structures of the pressure vessel, containment vessel, etc. which contain the debris can be air cooled without compromising their soundness. If air cooling becomes possible, the formation of new radioactive contaminated water through contact between the debris and cooling water will be halted. Currently, to avoid the flow of high-level contaminated water into the groundwater (and thus the ocean), the water level in underground pits inside buildings is being maintained at a level somewhat lower than that of the groundwater. (This means that groundwater inevitably flows into the underground sections of the buildings.) Changing over to air cooling would mean that if the management of the water level in the pits was suspended, the water level would automatically equilibrate and the flow would cease. The formation of new excess contaminated water would almost completely cease and it would no longer be necessary to increase the number of contaminated water storage tanks.[168] Naturally, the actual application of air cooling requires more precise data concerning the location and condition of the fuel debris, whether or not there is space to install new equipment such as pipes, the radioactive environment, and so on. TEPCO should take this seriously and make maximum efforts to achieve a shift to air cooling. It should consider the possibility of undertaking joint operations with domestic and overseas organisations that have submitted proposals through the International Research Institute for Nuclear Decommissioning (IRID) to shift to air cooling.

2-4-2 Immediate technical measures

The realisation of the air cooling discussed above will require a certain amount of time, during which

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[166] A construction method that prevents seepage of rainwater and cleaning water into the soil by the use of tarmac paving and so on.
[167] Fukushima Daiichi Nuclear Power Plant, Plant-related parameters, as of 5am on 6 February 2014, http://www.tepco.co.jp/nu/fukushima-np/f1/pla/2014/images/14020605_table_summary-j.pdf
[168] Sato S. (2014), "How can 1F be decommissioned?". [In Japanese] *Sekai*, January 2014 extra edition "1F Crisis", p.8.

roughly 400 ton/day of excess contaminated water will continue to be formed and the high-level contaminated water leaking from numerous locations on the site will continue to pollute the ocean. The following countermeasures must be taken as a matter of urgency in the meantime.

(1) The construction of large-scale tanks

In order to resolve the current rough-and-ready situation of contaminated water storage, the necessary number of large-scale 100,000-ton-class tanks should be constructed. Sufficiently high anti-flood dikes should be constructed around these tanks to avoid leakage to the sea even if leaks occur. This scale of tank is used in large numbers in oil refineries and as crude oil tanks in Japan's national oil stockpiling bases. Their technical reliability, including earthquake resistance, has been adequately established. The release to the ocean of tritium-containing contaminated water, due to the inability to remove tritium even after the introduction of the multi-nuclide removal equipment (ALPS), is unacceptable, and long-term storage of this water must also be carried out in the same way. Further, work to replace some 350 bolt-type sectional tanks on the site with welded tanks should be advanced in parallel with the installation of large-scale tanks, finally achieving a situation where all contaminated water is stored in large-scale tanks.

(2) Measures to prevent the inflow of groundwater and the flow of contaminated water to the sea

At present, even the groundwater flow routes have not yet been clearly defined. The preparation and execution of plans, based on geological and hydrological knowledge and an extensive survey, for the installation of a barrier and appropriate surface treatment must be implemented to prevent groundwater and surface water flowing into the contaminated site. It can be envisaged that the frozen earth barrier now being constructed to surround Units 1 to 4 will face problems arising from the inability to assess groundwater flow, the fact that a similar large-scale barrier has not yet been proven in practice, inability to withstand long-term use due to pipe corrosion, the fact that contaminated water will once again leak when the barrier is thawed out after use, and so on. There are also concerns that exposure of skilled workers during construction will cause difficulties for the completion of the barrier. For these reasons, it is imperative that a barrier that can withstand prolonged use be planned and installed. The new barrier should be one that completely surrounds the tank area and prevents the intrusion of external groundwater into the entire area that is currently contaminated (roughly 1-km square).

(3) Other measures

Improvement of the onsite environment through decontamination, removal of contaminated water from trenches, installation of a sea side barrier, prevention of dispersion of radioactive materials in the earth and sand in the harbour seabed must be implemented immediately and continually. In addition, urgent countermeasures are required to prevent the collapse of the Unit 1 and 2 exhaust stacks, parts of which have been severely damaged, and to ensure that, in the case that they do disintegrate, they do not fall on the side of the building that houses the spent fuel pool.

2-5 HOW SHOULD THE DESTROYED REACTORS BE FINALLY DISPOSED OF

[DETAILS]

1. Removal of fuel debris by the flooding method, which forms the basis of the government and TEPCO's Mid-to-Long-Term Roadmap, is nothing more than an illusion and, moreover, will entail a huge amount of radiation-exposed-labour. There is little option but to rely on air cooling of the stricken reactors while

drawing up plans to entomb them in a shelter to be passed down to future generations as humanity's "negative heritage".

2-5-1 Problems with the government and TEPCO's Roadmap

The government's Council for the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant finalised the formulation of its Mid-to-Long-Term Roadmap towards the Decommissioning of TEPCO's Fukushima Daiichi Nuclear Power Plant Units 1 to 4 on 27 June 2013. According to the Roadmap, the use of the flooding method to remove the molten fuel debris that remains in the pressure vessels and that has accumulated in the lower part of the containment vessels of Units 1-3 is planned to be carried out over a 30-40 year period, including a period for research and development. However, the realisation of this plan will require not only the resolution of numerous technical difficulties, but also the infusion of a gigantic budget and vast amounts of work that will entail exposure to radiation. Given the current predicament with the treatment of contaminated water, is this fuel debris removal plan really achievable?

The most troublesome hurdle facing this plan is the several hundred to 1,000 mSv/hr high-level radiation environments inside the buildings or on the operating floor of each building, which makes even accessing these areas a difficult task. Information about the location, condition and distribution of the fuel debris is based on little more than plain conjecture, and the location of damage to the containment vessels, which are scheduled for flooding, is unclear. Even the equipment and devices, including remote-controlled robots, that will be used to perform these surveys are still in their developmental stages, and should it be that there are stumbling blocks in the R&D process or the results of surveys show that the situation at the site is beyond the scope of original assumptions, implementation of the flooding method itself may then become impossible. These aspects also lead us to believe that only a very fine veneer disguises the fact that this plan may be nothing more than a gamble or simply an illusion.

Finally, there are also concerns about the soundness of the vessels themselves, since both the pressure vessels and the containment vessels have been exposed to high temperatures during the core meltdown and a corrosive environment due to the injection of seawater. At present, it is completely impossible to assess whether or not the leaks in the containment vessels of Units 1-3 can be repaired. We therefore find it hard to avoid a grave sense of doubt concerning the fact that the unilateral promotion of this mammoth project, costing several trillion yen and requiring the imposition of radiation-exposed-labour, rests on the premise that these leaks "can be repaired".

2-5-2 Current options

Is it really necessary to attempt to surmount the various difficulties mentioned above to remove the fuel debris? If, as mentioned in Section 2-4, it is possible to realise air cooling of the fuel debris, then the production of contaminated water will cease and the urgency to embark on a hazardous project premised on vast amounts of radiation-exposed-labour will recede. At the very least, the plan to remove the fuel debris should be frozen at this time, and a project to entomb the reactors in a sarcophagus, as at Chernobyl, considered while continuing to observe the attenuation of radioactivity over the coming 50-100 years.[169] There is absolutely no need to return the Fukushima Daiichi Nuclear Power Plant accident site into brownfield or greenspace (and anyway it is impossible to live there because of the contamination of the soil).

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[169] Sato S. (2013). Entomb in a Sarcophagus and Consign to the Future, in Azuma Hiroki (ed.), *Plan to Turn Fukushima Daiichi Nuclear Power Plant into a Tourist Attraction*,. [In Japanese] Tokyo: Genron, p. 89.

Instead, we believe that turning the site into a monument in the form of a sarcophagus would be an appropriate way of creating a permanent memory of this catastrophic accident as an example of the "negative heritage" of the human race.

2-6 WORKER HEALTH MANAGEMENT AND EXPOSURE REDUCTION IN THE PLANT SITE

[DETAILS]

For the time being, the following special measures and policies should be applied at the exceedingly difficult and dangerous worksite of Fukushima Daiichi, where the accident settlement and decommissioning of the destroyed power plant is being carried out.

1. A nuclear plant worker recruitment division should be set up within the national-scale "Agency for the Decommissioning of the Fukushima Daiichi Nuclear Power Plant (Fukushima Decommissioning Agency–FDA)", proposed in Section 2-3, to take direct charge of recruiting workers who will be engaged in the work of bringing the accident to an end and decommissioning the destroyed reactors at Fukushima Daiichi, and despatching these workers to the companies that will perform the various tasks. FDA will supervise working conditions and manage execution of the labour contracts at the employing companies.
2. A worker education and training centre should be established by FDA, at which practical training in specialised techniques, such as the theory and practice of radiation protection, pipe fitting and electrical work under conditions of high-level radiation will be given for a period of approximately one month, after which a qualification to participate in the work will be awarded only to trainees who pass an examination. (Much can be learned from the system carried out by the Ukrainian government for the decommissioning of the Chernobyl Nuclear Power Plant.[170])
3. Workers who have exceeded the limit for exposure should either be reassigned to work that does not entail exposure or be given assistance to find other kinds of employment.
4. Workers' wages should be substantially higher than those for workers in the same category who are not working under conditions of exposure to radiation.
5. Workers should receive a regular medical check-up (for example once a month) during the time they are working at the accident site. At the end of the work contract period, each worker's work record and dose record should be registered and the registered data handed to each worker as a health management logbook to enable both parties to engage in health management.[171]
6. Regular health check-ups (for example, once every six months) should be given after retirement. The actual check-up may be commissioned to existing medical institutions, but matters such as the components of the medical examination shall be determined by FDA's recruitment division, which will be responsible for this work. An assurance system shall be set up to make free lifetime medical care available for cases in which illnesses, including diseases other than cancer, are confirmed by check-ups.

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[170] Nippon TV production, NNN documentary "From Chernobyl to Fukushima: Examination paper for the future", broadcast on 27 October 2013.

[171] The 2010 proposal entitled "Unified Management of Exposure in Personnel Engaged in Work Involving Radioactivity" published by the Working Group to Consider Issues Associated with the Uses of Radiation and Radioactivity, a joint group consisting of the Basic Medicine Committee and General Engineering Committee of the Science Council of Japan, stated, "Almost 50 years have passed since the necessity for the establishment by an official body of a system for recording exposure doses to personnel engaged in work involving radioactivity was proposed by the Japan Atomic Energy Commission, among others, in the late 1960s, when commercial nuclear power generation began in Japan, but uniform management is still to be achieved." The current situation is that the Radiation Dose Registration Center for Workers that has been set up within the private organisation the Radiation Effects Association is carrying out this work, but this has become a problem due to reports of TEPCO's failure to register 1,295 workers (Tokyo Shimbun 30 June 2011) as well as neglecting to submit data for 21,000 workers (Tokyo Shimbun 28 February 2013).

7. In order to secure workers to engage in the accident cleanup and decommissioning at Fukushima Daiichi over the course of 100 years or more, in addition to the workers recruited by the mechanism noted above, a highly-skilled and public-spirited volunteer group of technical experts should be developed. At the same time, having clearly explained the dangerous and self-injurious nature of the work, a system of meritorious awards should be prepared while putting in place measures that will enable these people to work with pride in order to effect a smooth generational transition.

[DETAILS]

2-6-1 Exposure of nuclear power plant workers and human rights

Among the reasons why nuclear power plant systems are fundamentally incompatible with human rights, the most important is the problem of radiation-exposed labour. The longer a worker works the more the effects of exposure accumulate within the body, increasing the risks of cancer and other diseases. In other words, this is essentially labour that entails self-injury. Moreover, there is a great difference in exposure doses between regular power company staff and sub-contracted workers[172], and thus the burden of exposures has been unfairly placed on sub-contracted workers through the creation of a discriminatory employment structure. In the multi-layered sub-contracting structure, said to consist of seven to eight layers, sub-contracted workers are exposed to inhumane levels of intermediary exploitation. In this distressing worksite, the minimisation of exposure doses, strengthening of lifetime health management, improvements in the decency of employment, the securing of human resources, and the minimisation of discrimination should be carried forward and, through these, a system of nuclear power plant worker employment that does not run counter to the principles of the "restoration of humanity" (see Section 1-2) should be established.

2-6-2 Radiation-exposed labour at Fukushima Daiichi Nuclear Power Plant

Each day, on average, roughly 3,000 workers, more than 80% of these being sub-contracted workers, are being exposed to radiation while engaging in work to maintain the cooling system, monitoring and treatment of the contaminated water, clean-up of the site and various minor accidents that have occurred as well as preparations for decommissioning at Fukushima Daiichi.[173] [Update at the time of translation: The number of workers at the site has since more than doubled. As of January 2015, some 7,000 workers are entering the site each day.]

According to reports provided by TEPCO to the Ministry of Health, Labour and Welfare (MHLW), in the period March 2011 to the end of January 2014, 32,034 (TEPCO employees 4,102, subcontracted workers 27,932) people were engaged in work involving exposure to radiation at Fukushima Daiichi, of whom 173 received accumulated doses exceeding 100 mSv[174] and a further nine persons received doses exceeding 200 mSv. However, these figures do not include the doses for Self-Defense Forces' personnel, Fire Service rescue personnel, police officers and others who are thought to have received high exposure doses during emergency operations in the early stages of the accident. The collective effective dose (cumulative dose) to

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172 Accumulated worker exposure doses in power generating nuclear reactors (including Fugen and Monju) from FY1970 to FY2009 amounted to a total collective dose of 3,163.95 man-sieverts, which consisted of 179.2 man-sieverts for regular company staff and 2,984.75 man-sieverts for sub-contracted workers (Calculation by the Citizens' Nuclear Information Center based on data from the Ministry of Economy, Trade and Industry).

173 The sub-contracting rate (ratio of the total number of persons) was 86.3% according to the monthly summary of January 2014, and the rate for the cumulative total from March 2011 to January 2014 was 87.2%. Calculated based on TEPCO data released on 28 February 2014. [Update at the time of translation: According to the December 2014 summary (TEPCO press release, 30 January 2015), the monthly ratio was 90.7% and the cumulative total from March 2011 to December 2014 was 89.2%.]

174 Total of external and internal effective dose. Effective dose is the exposure dose equivalent to the whole body and differs from the thyroid gland exposure dose (equivalent dose) mentioned below.

workers, as far as we know from reports by TEPCO to MHLW, is 402.98 man-Sv[175], 74% of which has been received by sub-contracted workers. This figure amounts to a stunning 12.7% of the total cumulative dose[176] to workers in all Japan's nuclear power plants in the 40 years prior to the accident. [Update at the time of translation: The workers' collective dose continues to grow. Calculated again from TEPCO's monthly report to MHLW, workers' accumulated dose (March 2011 to December 2014) reached 493.72 man-Sv, 79.5% of which was received by sub-contracted workers. As of the end of 2014, the total number of exposed workers at the Fukushima Daiichi site was 40,569, of which 36,177 were sub-contracted workers.]

Since it is thought that during the emergency period immediately after the accident there were many workers who were not able to wear personal dosimeters due to insufficient provisioning, but who were working at the site without the accompaniment of a radiation exposure control staff[177], the full picture of worker exposure has not been elucidated. A large degree of uncertainty also surrounds the records of exposure doses to workers at the site. There is, for instance, the case of the discovery (in July 2012) of sub-contracted workers who had attempted to suppress their recorded dose rates by fitting lead covers over their personal dosimeters for fear that they would be discharged once they had reached the exposure dose limit.

Much doubt has been cast on whether the exposure doses and health management of the people working at the Fukushima nuclear power plant site have been handled appropriately. While the working conditions at the Fukushima site are far more severe than those at normal construction sites, it has been reported that even normal safety and health management practices enforced widely at construction sites are not being observed.[178]

In this situation we are far from being able to have confidence in worker exposure reduction or health management. There is a need for reform in each of the systems for worker recruitment and employment, exposure dose measurement, and health management, both during and after employment. In Germany, since exposure management is not left only to workers and employers but is also handled by a public body, workers wear two dosimeters, one of which must be submitted to the public body in its sealed state.[179] The very fact that workers themselves engage in actions such as working in high-radiation areas while hiding

[175] Calculated from the average exposure dose (effective dose) and the number of workers based on data (http://www.tepco.co.jp/cc/press/betu14_j/images/140228j0101.pdf) released by TEPCO on 28 February 2014. Further, the average exposure dose (whole body) per capita is said to be 23.61 mSv for regular company staff, 10.96 for sub-contracted workers, and 12.58 overall, with the highest individual exposure dose to a regular company staff member being 678.8 mSv and to a sub-contracted worker 238.42 mSv. These are heavily skewed toward the high dose rates associated with emergency work carried out mainly in the March to April 2011 period. More recently, the average and highest dose rates are far lower than these (looking at the external exposure dose summary of January 2011, the regular company staff member average was 0.32 mSv, the sub-contracted worker average was 1.08 mSv, the highest regular company staff individual dose being 4.15 mSv while it was 15.12 mSv for an individual sub-contracted worker). Note that regular TEPCO staff exposure doses were higher in the period immediately after the accident, but at present sub-contracted worker exposure doses are far higher than those of regular TEPCO staff. However, regular TEPCO staff are carrying out "specified high-dose tasks" (work for which the emergency exposure limit of 100 mSv is applied under the Ordinance on Prevention of Ionizing Radiation Hazards), and the above-mentioned regular TEPCO staff member, who received the 4.15 mSv individual dose was performing specified high-dose tasks. Looking at the most recent three months (November 2013 to January 2014), a total of 1,827 people were engaged in the performance of specified high-dose tasks and their collective exposure dose was 6.19 man-sieverts (also calculated based on TEPCO data released on 28 February 2014, total for internal and external exposure).

[176] See footnote 32.

[177] A manager who accompanies the workers at the worksite, and who measures workers' exposure doses, instructs workers on radiation protection, and so on.

[178] From reportage concerning excessively long 10-hour/day labour in the Tokyo Shimbun of 12 December 2013 and heat stroke in the Asahi Shimbun of 10 July 2011, and others. The Asahi Shimbun of 19 July 2013 reported that "It has been discovered at Fukushima Daiichi Nuclear Power Plant that there have been 2,000 workers, including estimates, who have received more than 100 mSv of exposure to the thyroid gland, a level at which cancer and other diseases are known to definitely increase." Figures indicated here are "equivalent doses" calculated by multiplying the "absorbed dose in Gy" by the "quality factor" for each separate organ or tissue. The effective dose mentioned above is the whole body exposure dose (the integrated "equivalent dose" for each organ after having taken the "tissue weighting factor" into account) found by addition after weights are assigned to each organ, and is a different method of assessment. These are easily confused since they use the same unit, the "millisievert" (mSv).

[179] Information from interviews conducted by Harutoshi Funabashi at the Rheinsburg Nuclear Power Plant and the Brandenburg State Ministry of Environment, Health and Consumer Protection, Germany, 24 and 25 February 2014.

their personal dosimeters in low-radiation areas because they fear discharge when they exceed their dose limit indicates that employment rules are fundamentally flawed. Workers who have exceeded their exposure limit should be treated with respect and either reassigned to work other than that involving exposure to radiation or given help to find new jobs.

2-6-3 Creating a work environment that instils workers with pride and purpose

Unbelievably sloppy mistakes are continually being made in the contaminated water treatment work. The causes of these mistakes probably stem from the shortage of skilled workers and insufficient worker training, low morale among workers, lack of experience and irresponsibility on the part of the TEPCO staff who are in overall control, and the inability to maintain normal calm common sense under conditions of high radioactivity. Reforming this dismal state of affairs would require conscientious worker education and the establishment of responsible onsite supervision, as well as the improvement of working conditions to the level where workers can feel a sense of pride and purpose in their work, but this cannot be realised simply by leaving the situation in the hands of TEPCO. To implement sufficient worker education, and to build a system for despatching workers to the companies that will perform the various tasks, it is necessary to set up a nuclear power plant worker recruitment division in a national-scale "Fukushima Decommissioning Agency (FDA)" that would directly recruit all workers to be engaged in the work to bring the Fukushima Daiichi Nuclear Power Plant accident to a conclusion and carry out decommissioning. In addition, it will also be necessary to supervise working conditions and ensure the full execution of labour contracts at the employing companies. Only by carrying through these fundamental reforms will it be possible to eliminate the intermediary exploitation caused by the inhumane multi-layered sub-contracting structure.

As there is no deterministic causal relationship between low-dose radiation exposure and health effects, this link is often difficult to prove. Many reports have shown that the health effects caused by the atomic bombing of Hiroshima and Nagasaki and the Chernobyl nuclear accident include a variety of illnesses besides cancers, but the official recognition of health damage is made difficult by the inability to show a clear causal relationship between radiation exposure and individual symptoms. This phenomenon is not limited to radiation exposure. It also occurred in the case of the organic mercury compounds that were the causal substances of Minamata disease. Of the 80,000 patients suffering from Minamata disease symptoms, a mere 5,000 were officially recognised as patients of the disease. The remainder were forced to simply accept the situation. Thus, for the radiation-exposed workers dealing with decommissioning the destroyed reactors and the contaminated premises, work which may be said to be a typical case of severe self-injurious labour, the precautionary principle should be applied to the greatest extent possible, and the assurance of lifetime medical treatment provided unconditionally. While handling these current issues in a robust manner, long-term arrangements for dealing with labour involving exposure to radiation must be completely revamped. This requires the foresight to look 100 years into the future and overlaps with the issue of securing workers who will perform the decommissioning work in the radioactive environment. Labour force shortages, especially shortages of skilled workers, are already apparent.[180] For this reason, in parallel with worker recruitment, it is necessary to begin work on the organisation of volunteer skilled workers.

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[180] Happy (alias for a worker at Fukushima Daiichi) and Yujin F. (2013). "All-Japan-System Needed to Bring the Accident to a Conclusion". [In Japanese], *Sekai*, Extra edition January 2014, F1 Crisis, p.61. Happy, (2013). *Diary of the Work of Bringing the Fukushima Daiichi Nuclear Power Plant Accident to a Conclusion: 700 days from 11 March*. [In Japanese] Tokyo: Kawade Shobo Shinsha.

It should be noted that we opted to discuss the decontamination work in the municipalities contaminated by radioactive materials released by Fukushima Daiichi Nuclear Power Plant in Section 1-6-4. Few nuclear power plant workers other than those at Fukushima Daiichi Nuclear Power Plant will be needed as long as the power plants are not restarted and remain in their cold shutdown state. The exposure doses to workers at other nuclear power plants is more than a factor of ten lower[181] than to those onsite at Fukushima Daiichi Nuclear Power Plant, and the 50 mSv/year (or 100 mSv over five years), the exposure limit before the Fukushima nuclear power plant accident, can be reduced to the German level of 20 mSv/year.[182]

[181] According to the publication The Network Concerned for Radiation-Exposed Labour, ed. (2012), *The Nuclear Power Plant Accident and Exposed Labour* [in-*exposure Labour*]. [In Japanese], Tokyo: San-ichi Shobo, p.9, the total exposure dose to workers during normal operation and regular maintenance work for the 75,988 workers at the more than 50 nuclear power plants and nuclear fuel facilities in Japan in FY2009 was 93.9 man-sieverts, or 1.10 mSv per capita per annum. The total accumulated dose from 11 March 2011 to 30 March 2012 for the total personnel of 20,549 at Fukushima Daiichi Nuclear Power Plant was 247 man-sieverts, or 12.02 mSv per capita per annum.

[182] The 2010 Recommendations of the European Committee on Radiation Risks (ECRR) recommend 5 mSv/year.