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Transportation of removed soils and wastes generated by decontamination activities, that contain radioactive materials released by the accident at TEPCO's Fukushima Dai-ichi Nuclear Power Station

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Abstract

The accident at Tokyo Electric Power Company's (TEPCO's) Fukushima Dai-ichi Nuclear Power Station (NPS) that followed the Tohoku District-Off the Pacific Ocean Earthquake, occurred on March 11, 2011, caused radioactive contamination. The national and local governments have been proceeding with off-site decontamination activities and the treatment of removed soils and wastes generated by them. In Fukushima Prefecture, construction of the Interim Storage Facility (ISF) was planned for the safe storage and management of removed soils and wastes which are temporarily stored in separate locations across the prefecture, until final disposal. Prompt and continuous transport of removed soils and wastes to the ISF is essential for the reconstruction and revitalization of Fukushima Prefecture.

In order to ascertain the safety and security of transporting a large volume of removed soils, the experimental transport program was implemented for about a year from March 2015. During this pilot transportation, approximately 1,000 m^3 of removed soils were transported from each of the 43 municipalities in Fukushima Prefecture. By looking at the three stages of the pilot transportation scheme: shipping from temporary storage sites (TSSs); transportation; and unloading at the ISF sites, the verification of the transportation was conducted regarding: (1) impact on residents; (2) impact on workers; and (3) efficiency and smoothness of operation. As a result, general safety throughout the whole of the transportation processes was confirmed. The MOE decided to proceed to the more rapid transportation from FY2016 onward, increasing the volume to be transported. The MOE plans to increase the volume in stages according to the progress made in land acquisition for the ISF, the construction status of the facilities, and the condition of the improvement of the road infrastructure within Fukushima Prefecture.

Introduction

On March 11, 2011, TEPCO's Fukushima Dai-ichi NPS in Fukushima Prefecture was seriously damaged by the Tohoku District-Off the Pacific Ocean Earthquake and the massive tsunami that

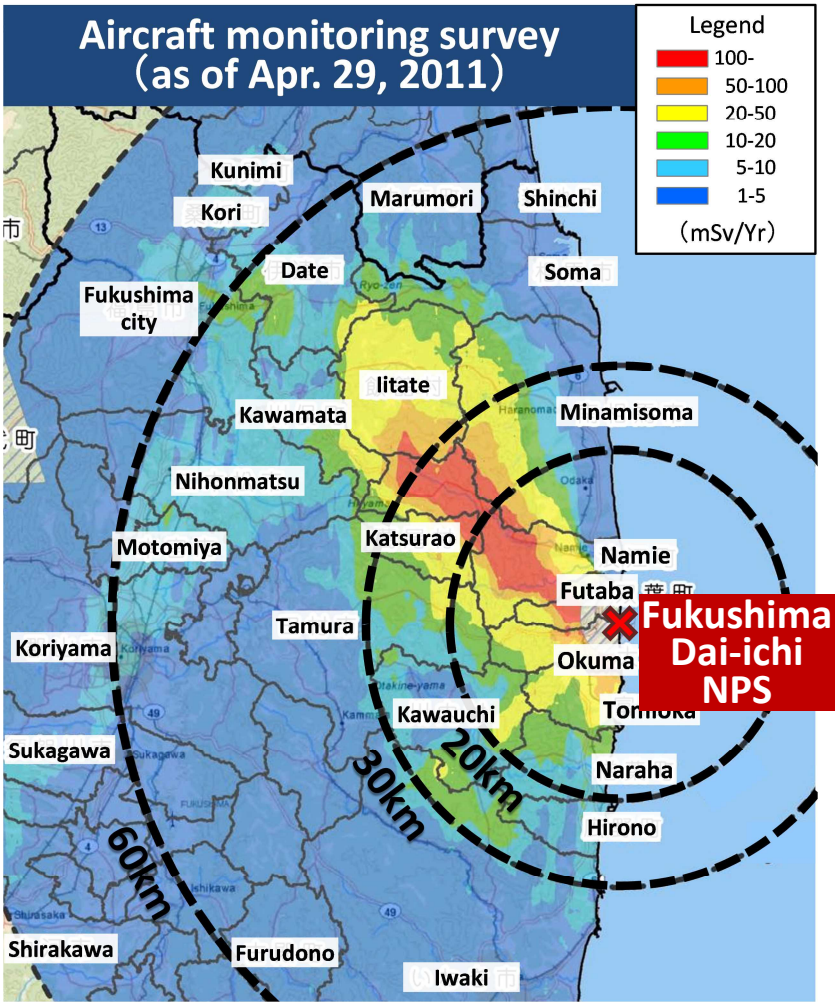
followed the earthquake, resulting in a massive amount of radioactive material released to an extensive area. This paper aims to report the progress on the transportation of removed soils and wastes generated from off-site decontamination activities to the ISF where they will be safely stored and managed in a centralized manner.

1. Off-site decontamination and the ISF

(1) Impact of the Accident at the Fukushima Dai-ichi NPS

Due to the accident at TEPCO's Fukushima Dai-ich NPS, a massive amount of radioactive materials were released. They created areas with an annual dosage in excess of 100 mSv/year extending up to 30 km from the site of the accident in the northwest (Fig. 1).

Considering these situations, Evacuation area was determined and classified to the three categories (Table 1).



Survey by Japanese Ministry of Education, Culture, Sports, Science and Technology (MEXT)／and U.S. Department of Energy (DOE)

Figure 1 Radioactive contamination resulting from the accident at Fukushima Dai-ichi NPS

Table 1 Categories of Evacuation Area

Category	Concept	Policy	Decontamination
Areas where it is expected that residents will face difficulties in returning for a long time	Areas where the dose exceeds 50 mSv/y, and there will be still not less than 20 mSv/y even after five years from the accident.	It should not be permitted to live for a long time.	to be partly carried out (reconstruction strong hold etc.)
Areas in which residents are limited not permitted to live	Areas there might be still not less than 20 mSv/y.	Continuing evacuation order to reduce exposure dose of residents.	To be carried out
Areas to which evacuation orders are ready to be lifted	Areas where it is confirmed that dose is certain to become less than 20 mSv/y.	Evacuation order is continued. Carrying out support measures quickly for recovery and reconstruction so that residents can return to home as soon as possible	To be carried out

Note／Each area was reclassified from the evacuation area as of December 26, 2011.

(2) Off-site decontamination

To deal with the radioactive contamination resulting from the accident, the national government decided to conduct “decontamination” to remove surface soils and wastes contaminated with radioactive substances, in accordance with a newly enacted law called the "Act on Special Measures Concerning the Handling of Environment Pollution by Radioactive Material". The MOE was designated to take charge of such decontamination activities. The activities have been proceeded in stages in close liaison with Fukushima Prefecture and related municipalities since January 2012 when the law was enacted. Decontamination areas are shown as colored areas in Fig.2, therefore, it is needed to decontaminate a vast area of land in Fukushima Prefecture. The decontamination in yellow, pale green and orange areas, that are designated based on the implementation plan, has been continuously carried out with the aim to be finished by March, 2017. It is targeted to lift the evacuation order in pale green and orange areas subsequently. The amount of soil, fallen leaves and tree branches removed during the decontamination works was expected to reach a considerable volume : total volume was estimated to be between 16 and 22 million m^3 after volume reduction (incineration) (Table 2).

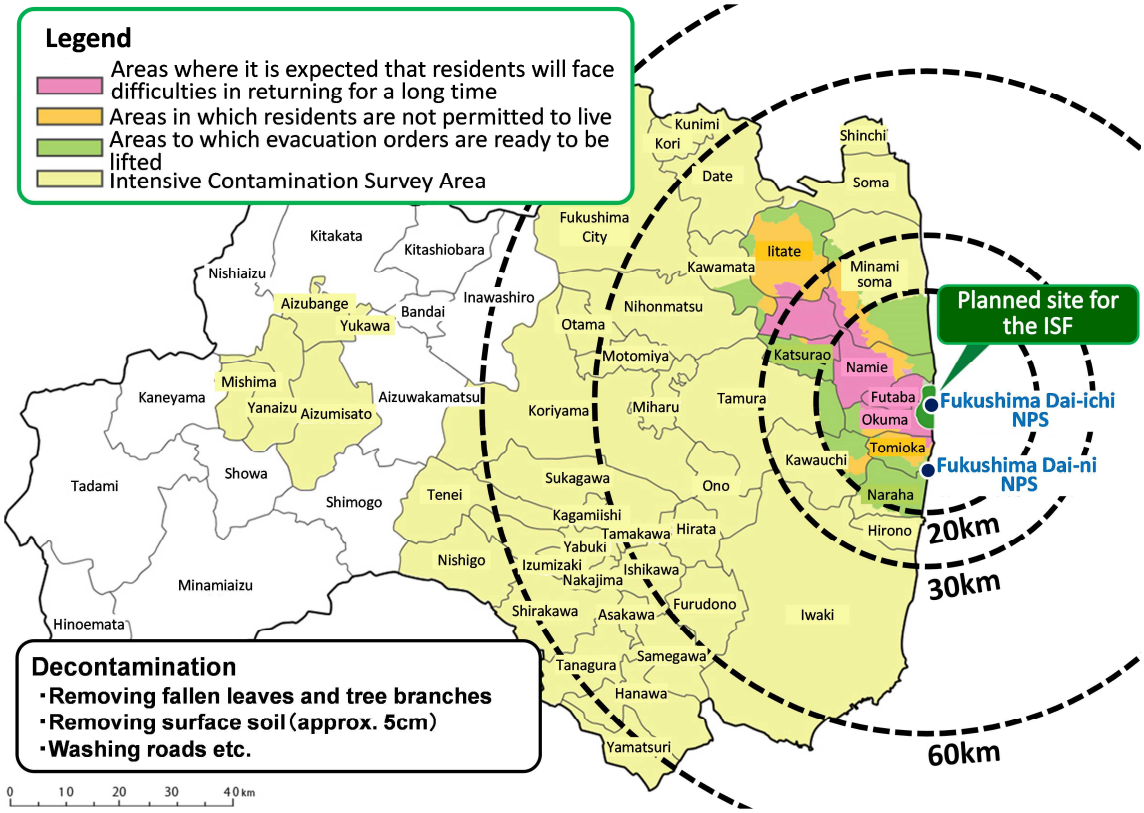


Figure 2 Decontamination areas within Fukushima Prefecture (as of August 2013)

(3) Interim Storage Facility

A massive quantity of removed soils and wastes generated by decontamination activities has been stored at various temporary storage sites (TSSs), which are mainly temporarily leased fields of rice, or has been buried in yards of houses, schoolyards or playgrounds. There are 1,085 TSSs (as of March 31, 2016) in Fukushima Prefecture, and it was decided that the ISF shall be established to concentratedly and safely store and manage soils and wastes in a centralized manner in accordance with the new law. The ISF was planned to be constructed close to the Fukushima Dai-ichi NPS as a facility to concentratedly and safely store and manage removed soils and wastes etc. generated by decontamination activities and other wastes with radioactive concentrations in excess of 100,000Bq/kg (Fig. 2). The future plan is to finally dispose them at sites outside Fukushima Prefecture in 30 years.

2. Transportation to the ISF

(1) Developing Basic Plan and Implementation Plan

Transporting massive quantity of radioactive soils and wastes across Fukushima Prefecture using

roads that people use daily and which are lined by countless numbers of houses was an unprecedented project. For the early reconstruction and revitalization of Fukushima Prefecture, it was essential to obtain the consent from residents in concerned areas and conduct transport work rapidly and safely.

Considering such a background, the MOE established in December 2013 “The Study Group on the Transportation of Removed Soils and Wastes to the ISF” consisting of the experts, to discuss basic issues regarding the transportation with a comprehensive approach. Based on the discussions by the group, the MOE compiled the “Basic Plan for Transportation of Soils and Waste to the ISF” in November 2014, which includes rules and guidelines for the transportation. Based on the plan, after coordination at the Transportation Coordination Council, consisting of concerned parties including Fukushima Prefecture all of its municipalities, and organizations on road traffic, the MOE developed the “Implementation Plan for Transportation of Removed Soils and Wastes to the ISF in FY2014–2015”. This plan articulates more concrete procedures of the transportation including workflow and routes targeting one year of transportation. The contents and other detail procedures are described below.

(2) Transportation vehicles and loading method

The removed soils and wastes stored at TSSs are packed in flexible containers that can hold approximately 1 m^3 each, and the surface dose rate (measured at 1 cm from the surface) of each container is 0.5 μSv/h on average. Some of the containers contained water inside and some were damaged by tree branches or other protruding matters contained in them; such containers had to be over-packed in containers with waterproof or watertight properties when transported. Currently, dump trucks with a gross vehicle weight of 20 tons are being used as transportation vehicles with consideration of availability and to maintain efficiency in loading/unloading, and to ensure safety. The cargo beds shall be covered with water proof/tight sheets to prevent the containers from falling off the trucks, and to prevent a stink and water escaping from the containers during transportation (Fig. 3).

In addition, transportation of incineration ash, which is expected to have a higher dose rate, is also planned after this fiscal year. The plan states that, at that time, appropriate measures shall be taken according to radioactive concentration levels in terms of further safety requirements such as to prevent scattering of the ash and to provide appropriate storage mode at the ISF. Specific measures are still under development. When incineration ash and other waste with radioactive concentration in excess of 300,000 Bq/kg is being transported, it shall be packed in containers that meet Type IP-2 Package standards to ensure safety, referring to existing regulations regarding transport of radioactive materials.

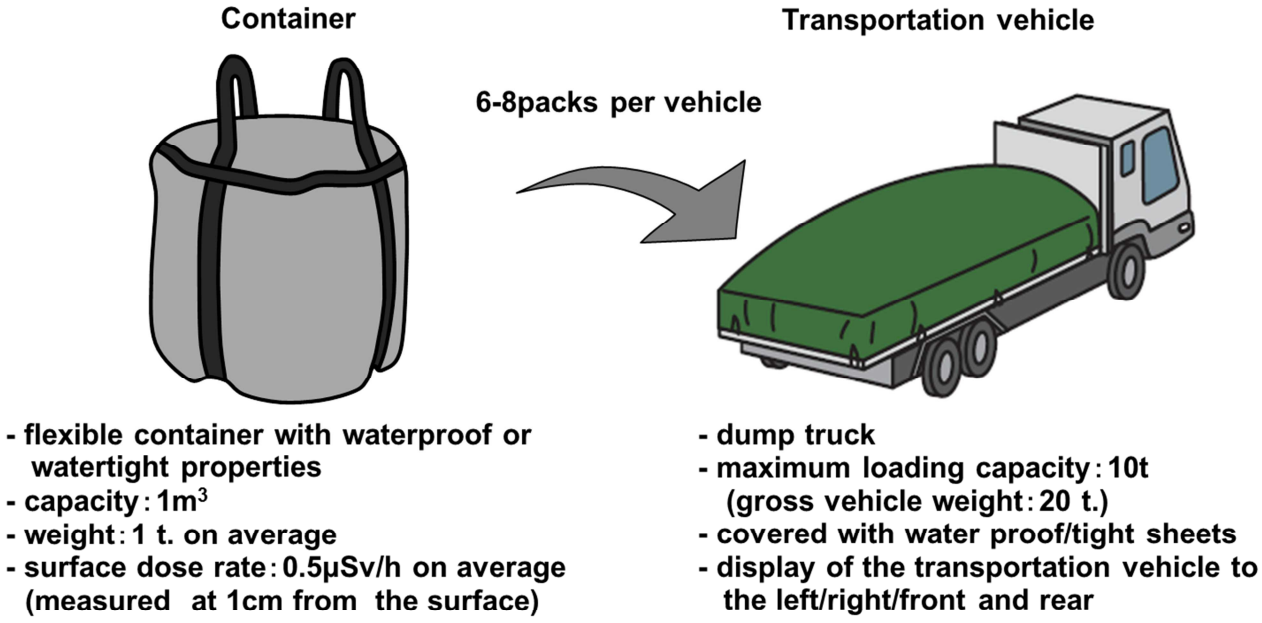


Figure 3 Loading method of the transportation vehicle

(3) Dose measurement of transportation vehicles before departure

The plan requires dose measurements before departure to ensure that the air dose rate at a distance of 1 m from the vehicle does not exceed 100 μSv/h in accordance to the Decontamination Guidelines. If it exceeds that limit, countermeasures including shielding and/or reducing the load shall be taken.

(4) Selecting transportation routes

Upon selecting a transportation route from a TSS to the ISF, not only is the required transportation time a major factor, but also the characteristics of each road along the route (e.g., traffic accident rates of each road type and the situation regarding houses along the roads) are taken into account. Therefore, comparison between routes with the shortest travel time and routes that use expressways to the maximum shall be made. Then transportation routes shall be established based on the rule that the basic transportation route shall be one that has enough distances from houses on the roadside and that uses expressways whose accident rate is 10% less than that of ordinary roads, considering local situations, even if such route may be longer in distance and/or time. The table below shows the distance of all road categories that will be included in all transportation routes based on the above principle (Table 3).

Table 3 Distance of transportation routes of each road category

Road category	Distance along transportation routes [km]
National expressways／Automobile highways (roadside access is controlled)	400
National highways	500
Other highways and roads	700
Total	1,600

Photo 1 Transportation on ordinary road

(5) Monitoring on transportation routes

Monitoring surveys shall be conducted on the transportation routes to evaluate the impact of transportation on the surroundings. Monitored items are shown in Table 4 below.

Table 4 Monitoring on transportation routes

Items	Description, assessment method	Principles for location selection	Number of locations
Dose rate	Radiation entering from carriageways to sidewalks is identified and its change by the time is used to measure the additional exposure dose. Evaluation is made by the accumulation of the value.	Intersections where transportation vehicles concentrate and stay longer, where more radiation exposure is expected. Also places where vehicles are likely to slow down due to road conditions.	7
Noise	Evaluation is made against the environmental standards. Comparison between the result before and after transportation is conducted.	Locations where the existing noise level is relatively high, and an increase in noise level due to transportation is expected.	12
Vibration	Evaluation is made against required limits. Comparison between the result before and after transportation is conducted.	The identical locations with noise-measuring locations.	12
Air quality	NO_2, suspended particulate matter, and dust. Evaluation is made against the environmental standards. Comparison between the result before and after transportation is conducted.	Locations with heavy traffic and where there are many houses along roads.	2

(6) Traffic measures

Transportation to the ISF is conducted via existing roads in principle. However, there are a substantial number of cases where the passage of a large number of heavy vehicles may not be possible. Thus, the planned road construction or improvement projects which have been started are taken into account, and the plan stipulates that appropriate traffic measures shall be taken (Table 5).

The measures are planned based on the assumed transport volume and the number of transportation vehicles, and implemented in advance of the expected increase in traffic due to the transportation.

Table 5 Traffic measures

Measures	Locations
Adding roads dedicated to the transportation	Places at sites where existing and planned roads will not be enough to handle heavy transport traffic. Part of the construction cost (approx. 50%) of the two additional interchanges shall be paid.
Increasing thickness of paving of existing roads	Increasing the thickness of paving of existing roads when the paving does not meet the standard for heavy traffic.
Settling parking spaces	Parking spaces for transportation vehicle are settled in consideration of long trips.
Placement of turnouts	Turnouts are placed on ordinary roads where the road is too narrow for two heavy vehicles to pass one another.
Installing convex traffic mirrors	Traffic mirrors are installed at places on ordinary roads with poor visibility and without enough sight distance ahead.
Repairing roads	Any damage caused by the passages of transport vehicles on the transport route is repaired.

(7) Real-time management of transported materials and transportation vehicles

All materials transported out of TSSs are packed in containers, each of which is identified with a unique ID to prevent possible loss of a container. All transportation vehicles are equipped with GPS devices to identify the current location to enable timely responses to troubles, including traffic accidents. The Operation Management System concentratedly manages the information regarding all transported materials and transporting vehicles. The information in this system can be utilized for responding in case of emergency such that a transportation vehicle is involved in a traffic accident. In addition, it is also used to instruct drivers to adjust time or to change routes in accordance with the situation of transportation and traffic regulation. (Fig. 4).

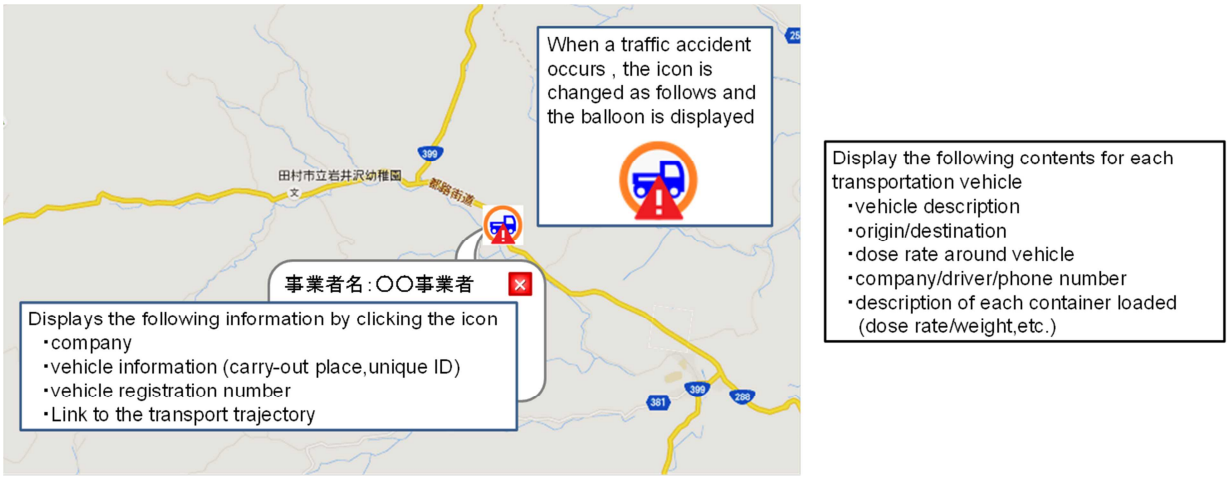


Figure 4 A display of the Operation Management System

(8) Developing system for post traffic accidents

There are deep-rooted concerns among residents that transportation vehicles loaded with radioactive soils and wastes could be involved in traffic accidents. Also, there is great interest in how general traffic can be diverted when the road is blocked for an extended period of time in the aftermath of such accidents. Therefore, to prepare for possible traffic accidents, the plan ensures the setting up of systems, including emergency contacts and a chain of command, with close cooperation with all relevant bodies including the police, the emergency services and road managers. Additionally, a contact and response system is also prepared in advance with contractors who will collect transportation vehicles involved in an accident and transported materials.

In preparation for such traffic accidents, the MOE has not only produced manuals on specific responses to an accident, but also has conducted joint trainings with all relevant bodies.

Photo 2 Training to collect scattered soils and wastes after traffic accident

3. Progress of transportation

(1) Transportation between FY2014–15 (Pilot Transportation)

FY2014 was the first year of transportation to the ISF. Upon the start of this unprecedented project in Japan, the MOE conducted the Pilot Transportation runs with the aim of confirming that transportation of removed soils and wastes can be conducted in a safe way. The amount of removed soils and wastes transported during the Pilot Transportation phase was approximately 1,000 m^3 from each of the 43 municipalities in Fukushima Prefecture—depending on the situation of TSSs in each municipality—totaling approximately 50,000 m^3. The yearly average number of transportation vehicles that make trips to and from the facility is expected to be approximately 25 vehicles.

During the Pilot Transportation phase, not only all safety measures as assumed and planned beforehand were taken, but also improvements to them were discussed and implemented based on problems that came to light in actual transportation.

(2) Verification of Pilot Transportation

Upon completion of approximately one year of the Pilot Transportation, the results were evaluated. The purpose of the evaluation was to verify the following points: whether the safety measures worked as expected; whether the safety of the residents and workers had been maintained; and whether the work had been conducted smoothly. Also the verification aimed to extract factors for additional measures needed as the amount of removed soils to be transported expands in the future, and renew the Implementation Plan for future transport and related construction work based on the findings. The verification was conducted for the items shown below (Table 6).

Table 6 Verification items regarding the Pilot Transportation

Category	No.	Verified items
(1) Loading sites	1)	Packing condition at loading sites
	2)	Requirements at loading sites
	3)	Air dose rates around transportation vehicles
	4)	Wastes generated at loading site
(2) Transportation	1)	Mode of packing
	2)	Parking spaces
	3)	Traffic safety
	4)	Emergency responses
	5)	Impact of radiation on residents along routes
	6)	Impact on living environment of residents along routes
	7)	Transportation while snowing
(3) Transportation management	1)	Operation management system
	2)	Measures to deal with communication blind zones
(4) Interim storage sites	1)	Monitoring of storage sites
	2)	Screening of the vehicles
(5) Cross cutting issues	1)	Radiation exposure management for workers
	2)	Consent and cooperation for smooth conduct of projects

The table below shows some parts of the evaluation result regarding technical items and items that residents are most concerned about (Table 7).

Table 7 Verification results (excerpt)

Verified items	Result and measures to take
Storage conditions	All wastes could be brought out from loading sites without any leakage due to repackaging in containers with waterproof or watertight properties, even though some of the original containers were torn or damaged.
Air-dose rate around the transportation vehicles	The air dose rates near the transportation vehicle (1 m from four sides of the vehicle) were measured at departure from the TSSs and all measures proved to be below 100 μSv/h. (Maximum dose rate was 13.5 μSv/h). More efficient methods of measurement need to be discussed as the number of the transportation vehicles increases in the future.

Loading method	Containers falling from the cargo bed and leakage or dispersal of removed soils and wastes were prevented by measures such as covering the cargo beds with waterproof/tight sheets.
Parking space	Parking spaces dedicated to the transportation vehicles were set up at Parking Areas on expressways, and public communication efforts were made. As a result, no complaints were made by general facility users. More dedicated parking spaces will be required as the number of the transportation vehicles increases in the future.
Traffic safety	As a result of infrastructural efforts including road repair, and human resource efforts like education and training sessions for the drivers, no traffic accidents occurred involving the transportation vehicles. Further traffic safety measures shall be taken as the number of the transportation vehicles increases in the future.
Impact of radiation on residents along routes	At monitoring locations like intersections, additional exposure dose proved to be small enough (accumulative 0.07 μSv during the pilot transportation at the maximum point). Monitoring continues.
Impact on living environment along routes	Levels of noise, vibration and air quality did not show significant changes before and during transportation, proving that the impact of transportation vehicles is minimal. Monitoring continues.
Smooth conduct of projects	Even though the initial number of inquiries received from the public was relatively high, it decreased as the public communication effort progressed as the transportation went on.

(3) Transportation plans in and after FY2016

Based on the verification results of the Pilot Transportation, a new Implementation Plan was developed for FY2016 with a proposed transport volume of 150,000 m^3 and the transportation started in April, 2016.

The volume of the transportation is expected to peak in 2020, following continuous effort by the MOE for land acquisition and construction of the ISF. If the plan proceeds as expected, the volume transported in 2020 is projected to be 6 million m^3. The accumulated volume transported by 2020 is estimated to be 5 to 12.5 million m^3 (Table 8).

Table 8 Current projection of transported volume

FY (Apr.-Mar.)	Amount of annual transport (estimation) [million m^3]
2014–2015	0.05
2016	0.15
2017	0.3 - 0.5
2018	0.9 - 1.8
2019	1.6 – 4.0
2020	2.0 - 6.0
Accumulation by 2020	5.0 – 12.5

It is projected that transportation vehicles will shuttle as many as 3,600 trips a day during the peak transportation period. The traffic around the ISF is expected to increase to a large extent due to heavy concentrations of transportation vehicles; however, simulations have shown that the traffic will not

exceed the traffic capacities of the roads on the routes, even at peak traffic time. In terms of radiation exposure and impact on living environment, none of the districts along the transportation routes are expected to see the monitoring results exceed the allowable limits with the exception that noise may exceed the standard in a few locations, caused by general traffic. It is expected that general traffic within Fukushima Prefecture will increase as reconstruction proceeds, so the MOE will continue monitoring and planning specific measures for transportation.

4. Conclusion

Smooth progress of the interim storage project is essential for reconstruction and revitalization of Fukushima Prefecture as a whole so it shall be forwarded as quick as possible, and it is indispensable to continue safe and secure transportation of removed soils and wastes, while implementing further improvements. Based on the verification result of the Pilot Transportation as well as issues that may be identified as transportation is conducted from now on, the MOE will continue with safer and more certain transportation with necessary additional measures and improvements in place.

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