



# Establishing Criteria for Reuse of Disaster Wastes Contaminated by the Fukushima Daiichi NPP Accident

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## 1. Background and goal of the present work

A part of the disaster wastes including concrete, metal and woods are contaminated by radioactive cesium released by the severe accident of the Fukushima Daiichi Nuclear Power Plant, and the large volume of the wastes remained untouched has obstructed the restoration of Fukushima. The volume reduction is urgent need.

Reuse of slightly contaminated wastes is effective for volume reduction of disaster wastes. Reuse of the contaminated wastes should be carried out based on ensuring the safety of radiation for the workers and the public by dose estimation approach. The Ministry of the Environment indicated on August 11, 2011 that the disaster wastes including the wooden wastes were reusable for unlimited purpose with the criteria of the total radioactive cesium ( $^{134}\text{Cs}$  and  $^{137}\text{Cs}$ ) concentration of 100Bq/kg. The Ministry of the Environment also announced the policy that the wastes containing radioactive cesium of higher than the 100 Bq/kg were reusable for limited construction materials such as subbase course materials of pavements.

As a first step, we derived the cesium concentration for the **limited purposes of reuse** based on two types of scenarios; **reuse for subbase course materials of pavements** and that **for embankment materials of seaside protection forest**. The calculated results concluded that concrete wastes **less than about 3,000 Bq/kg** can be used for two types of scenarios under the design conditions such as thickness of shielding materials.

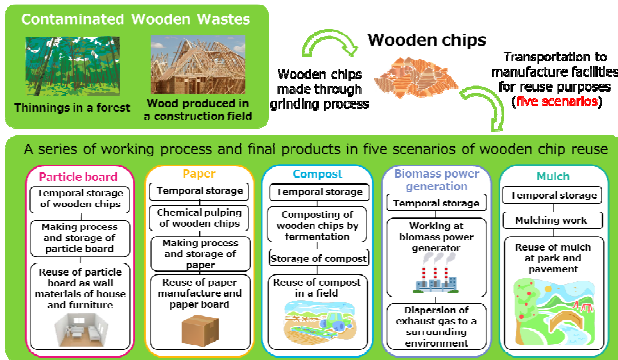
On the other hand, the criteria of 100Bq/kg for reuse of the general disaster wastes were determined, based on the existing clearance level of concrete and metal generated at nuclear power plants in Japan and not on dose estimation for reuse of wooden wastes. As a next step, it is important to confirm the validity of the criteria by the effective dose estimation for comprehensive scenarios relate to reusing wooden wastes. In this study, **we estimate the dose for reuse of wooden wastes to confirm the validity of 100Bq/kg in the present reuse.**

## 2. Methodology of dose estimation for reuse of wooden wastes

### 2.1. Scenario description

In general, wooden wastes, which are mainly originated from thinnings in a forest and wood produced in a construction field, are reused as wooden chips made through grinding process. In order to construct inclusive scenarios and their exposure pathways with reuse of wooden chips and to select parameter sets in the dose estimation for the exposure pathways, we investigated reuse purposes of wooden chips, final products made from wooden chips, a series of working process to make the products and their actual conditions in each reuse purpose around Fukushima.

Their reuse purposes are generally classified into five categories (scenarios); **particle board, paper, compost, biomass power generation, and mulch.**



Description of process that worker and public are possibly exposed by recycling of wooden chips

Working process and final products for five scenarios of wooden chip reuse are determined from the results of investigation. Exposure pathways to calculate the dose in five scenarios are determined from a viewpoint of radiation source volume, radioactive concentration in source, exposure time, types of exposure (external exposure and internal exposure) and so on.

### Description example of exposure pathways for particle board scenario

No.	Description	Radioactive source	Exposed individual	Category of exposure
1	Transportation		Worker	External
2	Residence near the transportation pass		Public (child)	External
3-5	unloading	Wooden chips		External, Inhalation, Ingestion
6-8	Work in a yard storing wooden chips		Worker	External, Inhalation, Ingestion
9	Manufacture of particle board			External
10	Work in a warehouse of particle board	Particle board		External
11		A wooden chip yard		
12		A wooden chip silo	Public (child)	External
13		A warehouse of particle board		
14-15	Construction of a house		Worker	Inhalation, Ingestion
16-17	Use of particle board		Public (adult, child)	Inhalation
18-19	Residence in the house (house and furniture)	Particle board	Public (adult, child)	External
20-21	Use of bed		Public (adult, child)	External

## 2.2. Parameter setting and calculation code

Parameters to calculate the dose for the workers and the public involved with the reuse of wooden chips were selected on the basis of this investigation. The dose conversion factors for each external exposure pathway is estimated under the condition of conservative source geometry related to the actual working conditions for transportation of wooden chips, temporal storage in the facilities and making process of final products around Fukushima Prefecture.

The values for the other parameters are cited from previous clearance level estimation in Japan[1], in the case of identifying that with the previous value. We used PASCLR2 code[2], which was developed for deriving the clearance levels, for a series of the dose estimation to exposure pathways with unit total radioactive cesium concentration (1Bq/kg) of wooden chips under the assumption of concentration ratio of  $^{134}\text{Cs}/^{137}\text{Cs}=0.535$ .

## 3. Result of dose estimation

Based on the results of calculated dose, we derived the minimum radioactive cesium concentration ( $^{134}\text{Cs} + ^{137}\text{Cs}$ ) which is practicable for the reuse of wooden chips, corresponding to the effective dose criteria indicated by Nuclear Safety Commission of Japan (**1mSv/y for engaging in treatment of materials contaminated by the severe accident, and 10μSv/y for post-closure in disposal and for reuse of contaminated materials**)[3].

The calculated radioactive cesium concentrations in wooden chips for main pathway are shown in the following Figure, corresponding to the effective dose criteria. It is indicated that the minimum radioactive cesium concentrations in each scenario are calculated to be 120Bq/kg for particle board, 1,900Bq/kg for paper, 2,700Bq/kg for compost, 2,200Bq/kg for biomass power generation and 260Bq/kg for mulch, respectively.

Scenarios	Main Exposure pathways in scenario of reusing wooden chips		Total radioactive cesium concentration in wooden chips corresponding to the effective dose criteria (Bq/kg)	Minimum radioactive cesium concentration in each scenario (Bq/kg)
	External	Internal		
Particle board	Work in a storage yard of wooden chips	External	120	120
	Residence near particle board factory (child)	External	120	
	Use of bed (child)	External	120	
Paper	Work around a black liquor tank	External	1900	1900
	Maintenance of a recovery boiler	External	1900	
	Residence near the paper factory (child)	External	1900	
Compost	Transportation of wooden chips	External	2700	2700
	Agriculture in a field containing compost	External	2700	
	Ingestion of crops grown in the field (adult)	Internal	2700	
Biomass power generation	Work around a storage silo of wooden chips (child)	External	2200	2200
	Maintenance of an incinerator	External	2200	
	Inhalation of dust released from the incinerator (child)	Internal	2200	
Mulch	Work of mulching wooden chips in a park	External	260	260
	Use of mulched park (child)	External	260	
	Use of mulched pavement (child)	External	260	

1E+01 1E+03 1E+05 1E+07

- ✓ The calculated doses for external exposure pathways are larger than that for internal exposure pathways (ingestion and inhalation), and these pathways indicates the minimum cesium concentrations in each scenario.
- ✓ Especially, their minimum cesium concentrations are characterized with the conditions of low dilution factors (ex. use of bed made of particle board and use of mulch) or enrichment process (ex. Maintenance of a recovery boiler and of an incinerator).
- ✓ The lowest radioactive cesium concentration is calculated to be 120Bq/kg for the pathway of using bed in particle board scenario.

Description of process that worker and public are possibly exposed by recycling of wooden chips

## 4. Conclusions and future work

- ✓ All radioactive cesium concentrations in wooden chips corresponding to the effective dose criteria are more than the criteria of 100Bq/kg for reuse, which confirms the validity of 100Bq/kg in the present reuse of wooden chips.
- ✓ On a present work, we are performing analyses for the reuse criteria of a vast quantity of **removal soil** generated by environmental decontamination activities, in which **effective reusing method** are under consideration. Reuse of the removal soil will be indispensable to the smooth Fukushima restoration.

### References

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