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Efforts to Mitigate Radioactive Contamination of Farmland Environment.

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Radioactive contamination of vast area including crop land with a focus on TEPCO Fukushima Daiichi nuclear power plant accident in March 2011, still ask farmers to inhibit the uptake of radioactive material to the crops in the farmland even today a lapse of two years. In this poster, removal technology from the surface soil layer of radioactive cesium in paddy and upland soils, separation of radioactive cesium from soil, and potassium fertilizer application to reduce the uptake of radioactive cesium to the edible part of plant. All studies are efforts to reduce the concentration of radioactive substances in food less than standard value. Furthermore, it should be mentioned that not only for the food contamination, but also it should be paid the attention to reduce the radiation exposure of farm workers. In the poster, not only the technical procedures but also obtained results of actual decontamination process in the farm which have been carried out in the contaminated area will be presented.

Reduction of air dose rate

- Reduce external exposure of local resident
- Target: 1 mSv/year
- Surface soil layer radioactive materials is most effective
- Detected by survey meter

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Decontamination of agricultural field

Protection of contamination

- Protect internal exposure by food intake
- Target: 100 Bq/kg
- Plow layer soil is important
- Detection is mainly done by using germanium semiconductor detector

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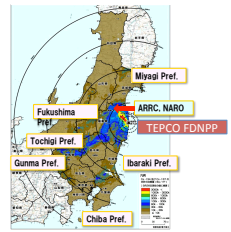
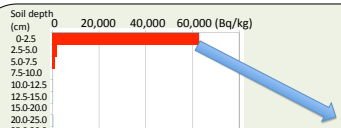
Migration reduction to agricultural products



Distribution map of radioactive Cs (134 + 137) dose map (MEXT, 2011. Oct)



Behavior of deposited radioactive cesium in a typical paddy soil in Fukushima prefecture where has not disturbed after the explosion.

Extraction efficiency (%)

Soil type	Extractants H_2O	1M NH_4Ac
Paddy soil	ND*	2.3%
Upland soil	ND	5.3%

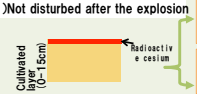
*ND < 0.4 Bq/L

Particle size fractionation of radio cesium in 0-2.5 cm layer

Soil texture	Grain size (μm)	Relative ratio (%)	Bq/kg	Bq/total	Bq ratio(%)
Clay	– 2	4.8	174,300	8,400	13
Silt	2 – 20	29.6	103,300	30,600	46
Fine sand	20 – 200	45.2	48,000	21,700	33
Coarse sand	200 – 2000	20.4	25,900	5,280	8

Example trial in special decontamination area

1)Not disturbed after the explosion



Top soil stripping — Disposal of soil is required
Top soil removal is most effective method to remove radioactive cesium from the farm land. (Est. cost is 500,000 USD/ha – ca. 20,000 ha, AIST 2013)
Soil 10,400 Bq/kg→2,600 Bq/kg
Air dose 7.14 μSv/h→3.39 μSv/h

Inversion tillage — Sufficient soil depth is required
Soil redistribution operates by dispersing the strongly particle reactive cesium from a thin surface layer (typically less than 5 cm thick) into a deeper layer.
Air dose 0.7 μSv/h→0.3 μSv/h

2)Disturbed after the explosion

Deep ploughing — Dilution by ploughing
When the soil radioactive cesium concentration is not high, dilution by mixing the deeper layer soil reduce the concentration. (Cheapest way)

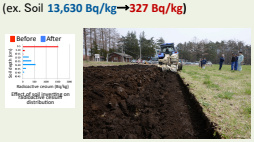
Paddling and suspension removal (paddy soil) — Disposal of soil (clay) and water is required
As most of the radio active cesium fixed to the small particle in soil, they can be removed separately.
Soil 15,254 Bq/kg→9,689 Bq/kg
Air dose 7.6 μSv/h→6.5 μSv/h

Cost for decontamination is mainly dependent on how to manage the removed soil. Cost for Interim Storage Facility (still not start construction) and Provisional storage account for over 90%.

Optional methods for soil stripping.

1) Top soil stripping with soil hardener. Mg-P compounds were spread on the top soil then hardened stop soil layer is removed. The merit of this method is visualization of the target soil. (ex. Soil 9,090 Bq/kg→1,671 Bq/kg, Air dose 7.8 μSv/h→3.6 μSv/h)
2) Removal of top soil with turf and pasture. When the vegetation (incl. weed) develops like turf, most of radioactive cesium remained in the vegetation. (ex. Soil 13,630 Bq/kg→327 Bq/kg)

Top soil stripping



Inversion tillage

Paddling and suspension removal

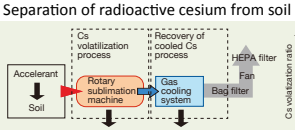
Top soil stripping with soil hardener

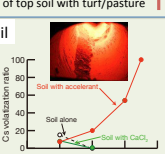
Removal of top soil with turf/pasture

Application techniques at different soil contamination levels (MAFF)

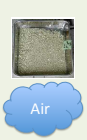
Radioactive cesium (Bq/kg) in soil (0-15 cm)	Application techniques
~ 5,000 (Bq / kg)	Inversion tillage, top soil stripping, **migration reduction**
5,000 ~10,000 (Bq / kg)	Top soil stripping, inversion tillage, paddling and suspension removal
10,000 ~25,000 (Bq / kg)	Tops soil stripping
25,000 (Bq / kg)~	Top soil stripping with soil hardener, removal of top soil with turf/pasture

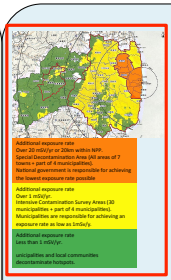
Separation of radioactive cesium from soil

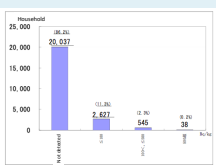




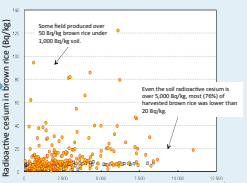
Example trial of decontamination of soil
Soil 1
56,000 Bq/kg → <45 Bq/kg
Filtered air
ND (<0.18Bq/m³)
Soil 2
67,300 Bq/kg → <46 Bq/kg
Filtered air
ND (<0.18Bq/m³)



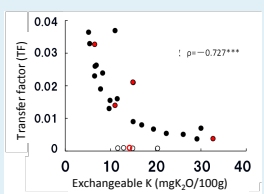




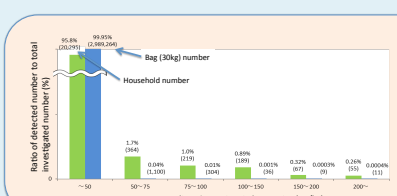
Radioactive cesium concentration of brown rice grown in Fukushima Prefecture, cultivated in 2011 outside of Special Decontamination Area (Fukushima Pref. 2012.)



(MAFF, Fukushima Pref)



Brown rice were cultivated in 2011 outside the special decontamination area. But some field produced >100 Bq/kg brown rice. Soil Cs 134+137 level did not explain the result. The exchangeable K content in the soil is most important to explain the transfer factor of radioactive cesium. Based on this, when the soil contamination level is under 5,000 Bq/kg, the exchangeable K content should be over 25 mgK_2O/100g, which makes the transfer factor lower than 0.01. Which means the radioactive cesium content in the brown rice is lower than 50 Bq/kg.



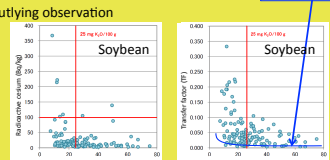
For the rice cultivation after 2012, guidance of each prefecture was clearly indicated to be higher than 25 mg K_2O/100g. Which greatly decreased the level of radioactive cesium in the brown rice after 2012.

Issues faced after 2 yrs and half.

Decontamination waste

Huge amount of decontaminated soil and biomass are left. Some progress to extract radioactive cesium and volume reduction experiments are going on.

Outlying observation



In some crops (e.g. soybean, buckwheat, etc.), relatively high transfer factor was observed in rare case even though the soil exchangeable K level is high. The mechanism is under investigation.