Radioactive contamination of Japanese agricultural soil and plant caused by the Fukushima nuclear accident

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Fukushima Daiichi NPP (Nov.15, 2011)
Today’s topics

1. Outline of the accident and emission of radioactive substances to environment.

2. Direct radioactive contamination of vegetable just after the accident.

3. Spatial distribution of radioactive Cs in agricultural soil.

4. Radioactive Cs contamination of rice in Fukushima Prefecture.

5. Decontamination methods.
1. Outline of the accident and release of radioactive substances.

Fukushima Daiichi NPP (Nov.15, 2011)
Fig. 1 Amount of estimated major radioactive substances (above 1PBq) released from the Fukushima Daiichi NPP into the atmosphere (Nuclear Emergency Response Headquarters, 2011)
Fig. 2 Changes in cumulative values of main radioactive substances released from the Fukushima Daiichi NPP into the atmosphere (TEPCO, 2012)
Fig. 3 Accumulation of radioactive Cs calculated by air survey at Nov. 1, 2011 (MEXT, 2011) and radioactive contamination routes (Hayakawa, 2011)

Radioactive Cs: Cs-134+Cs-137
2. Direct radioactive contamination of vegetable just after the accident.

Preliminary check for radioactive contamination of vegetables by using GM survey meter (Mar 18, 2011)
Direct contamination: deposit from atmosphere and uptake through leaf and body.

Indirect contamination: uptake through plant roots from soil after accumulating to soil.

Mixed contamination: uptake from soil and water through stem or body.

- Direct contamination is important just after accident.
- Indirect contamination continues long time after stopping fall out.

Fig. 4 Uptake route of radioactive substances to plant.
Radioactive monitoring upland field in NIAES

Isotope research building in NIAES

Direct Contamination

Emergency manual of sample determination at nuclear accident

Ge detecting system of NIAES
Mar～Jun, 2011

Radioactive Cs concentration (Bq/kgFW)

Above 500 Bq/kg: 3.9%

July, 2011～Mar, 2012

Radioactive Cs concentration (Bq/kgFW)

Above 500 Bq/kg: 0.05%

Fig.7 Radioactive Cs concentration in vegetables (MAFF, 2012)
3. Spatial distribution of radioactive Cs in agricultural soil.

Soil sampling at paddy field near Fukushima Daiichi NPP (Nov.15,2011)
Fig. 8 Procedure of creating distribution map of radioactive Cs concentration in agricultural soil
Fig. 9 The correlations between radioactive Cs concentration and air dose rate at different soil and land use units.
Fig.10 Distribution map of radioactive Cs concentration in agricultural soil from Iwate to Shizuoka Prefecture collected at Nov. 5, 2011 (MAFF, 2012)
Fig. 11 Distribution map of radioactive Cs conc. in agricultural soil at Fukushima Prefecture collected at Nov. 5, 2011 (MAFF, 2012)
Fig.12 Distribution map of radioactive Cs conc. in agricultural soil at Fukushima City collected at Nov. 5, 2011 (MAFF, 2012)
4. Radioactive Cs contamination of rice in Fukushima Prefecture.

A rainfall meter and basin for collecting precipitation Cs at paddy field of Fukushima Prefecture
Fig. 13 Radioactive Cs concentration in brown rice at Fukushima Prefecture, 2011 (MAFF, 2012)
Fig. 15 Relationship between radioactive Cs concentration in soil and brown rice (Fukushima Prefectural Government, 2011)
Fig. 16 Relationship between soil exchangeable potassium content and radioactive Cs concentration in brown rice (Fukushima Prefectural Government, 2011)

- Average in Fukushima City: 15.9 mg/100g
- Average in Japan: 28.5 mg/100g

Regression equation:

\[ y = 1673.3e^{-0.164x} \]

Coefficient of determination: \( R^2 = 0.6279 \)
Fig. 17 Vertical distribution of radioactive Cs concentration in paddy soil (Fukushima Prefectural Government, 2011)
5. Decontamination methods.

Model experimental paddy field for method of mixing soil and removed contaminated soil using water in Fukushima Prefecture.
Table 2 Radioactive Cs concentration in 15cm soil depth (Nagasaka et al., 2012)

<table>
<thead>
<tr>
<th></th>
<th>Before removing (Bq/kg)</th>
<th>After removing (Bq/kg)</th>
<th>Reduction rate (%)</th>
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<tr>
<td>Paddy</td>
<td>15,180</td>
<td>2,801</td>
<td>82</td>
</tr>
</tbody>
</table>

Surface soil crushing
Scraping surface soil
Accumulating soil and carrying out

Fig.18 Removing field top soil (MAFF, 2011)
Reduction rate of radioactive Cs in 15 cm soil depth after treatment: $29\sim71\%$

Fig. 19 Mixing soil and removed using water (MAFF, 2011)
Fig. 20 Vertical distribution of radioactive Cs in soil after A) deep plowing and B) conventional plowing (MAFF, 2011)
Table 3  Radioactive Cs concentration and transfer factor of Sunflower (Fukushima Agricultural Technology Center, 2011)

<table>
<thead>
<tr>
<th>Sample / Treatment</th>
<th>Acceleration*</th>
<th>Suppression**</th>
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<tr>
<td>Seed (Bq/kg FW)</td>
<td>3.2</td>
<td>5.0</td>
</tr>
<tr>
<td>Stem &amp; Leaf (Bq/kg FW)</td>
<td>32.4</td>
<td>31.3</td>
</tr>
<tr>
<td>Soil (Bq/kg DW)</td>
<td>1,045</td>
<td>1,134</td>
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TF from Soil to Seed       0.0031       0.0044
TF from Soil to S&L        0.031         0.028

* : Acceleration: (NH₄)₂SO₄ + no K  
** : Suppression: NH₄NO₃ + KCl
Conclusions

- The main nuclide of radioactive contamination in agriculture is radioactive Cs.
- Radioactive Cs released from Fukushima Daiichi NPP is distributed in agricultural soil from Tohoku to Kanto district.
- Area of radioactive cesium concentration above 5,000Bq/kg was estimated 8,900ha in farm land at Nov 5, 2011.
- There are many factors of rice contamination.
- Physical methods are only effect for decontamination.