“USE of Simulation Capabilities of the ERMIN by FAIRDO Project after Fukushima”

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OUTLINE

1. Overview of FAIRDO project

2. Research Activities

3. Research Results
   3-1. Application of ERMIN (Okuma town)
   3-2. Application of ERMIN (Tomioka town)
   3-3. Comparison of decontamination strategies (Tomioka town)
Objective:

FAIRDO (Fukushima Action Research on Decontamination Operation) aims at providing substantive inputs to the ongoing decontamination/remediation operations, reflecting the realities of local conditions for effective designing and implementation.

Components and mode of operation:

(1) Governance for Effective Remediation/Decontamination Operations

Prof. Hiroshi Suzuki, Fukushima University/Chair of Reconstruction Committee in Fukushima Pref. With IGES and Institute for Advanced Sustainability Studies (IASS) Tokyo Keizai University, Chiba University of Commerce, Nagoya University, Karlsruhe Institute of Technology (KIT)

(2) Development of remediation/decontamination strategies reflecting the local conditions

Tokyo University of Agriculture and Technology, Fukushima University, KIT, Bundesamt fur Strahlenschutz (BfS)

(3) Effective communications to promote collaboration with those affected in contaminated areas

Tokyo Institute of Technology, Fukushima University, Berlin Freie Universitat.

Major outputs/outcomes:

- Substantive inputs to the ongoing decontamination/remediation operations through relevant experts’ channels
- Japan optimal model based on EURANOS/RODOS developed
- Guidelines for effective decontamination/remediation operations shared
Overview of FAIRDO Project

FAIRDO’s messages

Toward better decontamination and recovery

Integrated discussions and planning of decontamination and recovery

Better communication among municipalities on their experiences and lessons

Development and utilisation of tools to understand and reflect local situations in decontamination/recovery

Establishment of the Information Platform to facilitate information sharing and ensure transparency/credibility

Review of the current decontamination plans to include clearer visions toward recovery and development of the local societies

Introduction / dissemination of participatory decontamination planning and implementation

Development (or review) of local reconstruction plans envisaging that some of radioactive matters aren’t cleared even after decontamination

Application of brief assessment

Utilisation of RODOS model to enable clear understandings of effects, costs, amounts of wastes and workloads.

More utilisation of experts such as Decontamination Promotion Workers

Establishment of community roundtables at each municipality
Research Activities

- Application of ERMIN into “Okuma Town Office” and “Yo-no-mori at Tomioka town”
- Comparison the simulation results and actual decontamination plan (as of model project)
- Reproducibility improvement and sensitivity analysis of ERMIN
- Comparison results of decontamination strategies
2 Overview of RODOS

RODOS

Countermeasures on immediately after the accident

Weather model and atmospheric dispersion model

Long term countermeasures

ERMIN
(Urban Area model)

HDM
(Hydrological model)

Computable on effects of measurements and the cost.

AgriCP
(Agriculture model)

FDMF
(Forest model)

etc.

Compare the strategies
Overview of ERMIN model

User Inputs:
- Reference surface deposition
  - $x$ Bq m$^{-2}$

Environment description

Countermeasure strategy

ERMIN Model:
1. Calculate initial deposition on urban surfaces
2. Calculate retention on each surface as a function of time
3. Apply library of dose rates to calculate dose and dose rates from each surface as a function of time
4. Modify surface contamination and dose rates to represent countermeasures

Outputs:
- Surface contamination and dose-rate
- Resuspension
- Indoors, outdoors and average public dose
- Dose to recovery workers
- Waste amount and activity concentration
- Effort and cost

Reference: EURANOS
3. Research Outcomes

3-1. Applying ERMIN to Okuma town office

- Calculate air dose rate at residential area (indoor and outdoor)
- Predict exposure of residents (normal living)
- Predict exposure reduction through decontamination
- Predict differences of exposure caused by decontamination with the consideration of time

3-2. Applying ERMIN to Tomioka town (yonomori) and
3-3. Comparing decontamination strategies

Comparison on methodologies, places, results of decontamination, regarding with the five points of view

- Possibility of Development of decontamination strategies reflecting local conditions
Applying ERMIN to Okuma town office and the environmental setting

Purple: model project area by JAEA  Green: calculation area

Calculating area of environmental media by using GIS  Input data into ERMIN
3-1 Estimation of Initial Deposition

Before of decontamination

After of decontamination

Average air dose rate: 11.5 μSv/h

Average air dose: 3.9 μSv/h

Conditions

Before decontamination:
- Date of deposition: 2011, Mar. 21st
- Initial deposition: 1.79 × 10^6 Bq/m²

Reference: JAEA

Inverse Calculation of Cs decay

\[
\text{Inverse dose rate (μSv/h)} \rightarrow \text{deposition (Bq/m}^2\text{)}
\]

Conversion factor:
- Natural radiation from soil: 0.04 μSv/h
- Ratio of 134Cs to 137Cs from FDNPP: 1:1
- Conversion factor: 134Cs: 5.4 × 10^{-6}, 137Cs: 2.1 × 10^{-6}

(Unit: [μSv/h]/[MBq/m²])

IAEA-TECDOC-1162
## 3-1 Input of Decontamination Parameters

### Road surface removal

### Top soil and turf removal

#### Methods and parameters of decontamination

<table>
<thead>
<tr>
<th>CM</th>
<th>Waste</th>
<th>Waste rate [kg/m²]</th>
<th>Depth removed [m]</th>
<th>DF</th>
<th>Team size</th>
<th>Work-rate [m²/team.hr]</th>
<th>Equipment cost [€/m²]</th>
<th>Material cost [€/m²]</th>
<th>Labour cost [€/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil and turf removal (mechanical)</td>
<td>Soil and turf</td>
<td>60 30</td>
<td>0.05 0.02</td>
<td>20</td>
<td>2 8</td>
<td>400 66</td>
<td>0.09</td>
<td>0</td>
<td>0.2 5.3</td>
</tr>
<tr>
<td>Road surface removal</td>
<td>asphalt</td>
<td>60 11.2</td>
<td>0.04 0.005</td>
<td>8</td>
<td>2 9</td>
<td>400 173</td>
<td>0.2</td>
<td>0.1</td>
<td>0.2 3.9</td>
</tr>
</tbody>
</table>

- Black: as default value of ERMIN
- Red: as adjusted parameters in Japan based on the model project of JAEA

Reference: JAEA
3-1 Radiation Dose (indoor) from Contamination

- Behavior of each environmental media
- Decontamination effect

Identify contribution of Environmental medias to Radiation Dose

Surface contamination $[\text{Bq/m}^2]$ over time.
3-1 Radiation Dose (outdoor) from Air Dose Rate

Decontamination

- Identification of transition of contamination and the radiation dose (indoor and outdoor).
- Reflection of trends of air dose rate

94% of radiation dose is contributed from soil.

Fitting was difficult due to the lack of un-measured data.

However, the result shows the trends semi-quantitatively.
3-1 Integrated Additional Exposure

Precondition

- normal living (indoor:16 h)
- dose reduction factor is differ from buildings
- presence time is proportional to environment description
- mooing range is only one grid

Calculation Result

- Predict exposure reduction through decontamination
- Predict differences of exposure caused by decontamination time

Without CM

With CM

Reduction effect of integrated additional exposure by decontamination

Decontamination

10 mSv

1 year
3-2 Applying ERMIN to Tomioka town (Yonomori) and the environmental setting

Purple: model project area by JAEA  Green: calculation area
Red: mesh ID  Yellow: monitoring point number

Calculating area of environmental media by using GIS  Input data into ERMIN
Estimation of Initial Deposition

Estimation of initial deposition

Inverse calculation of Cs decay

Air dose rate (μ Sv/h) → deposition (Bq/m²)

Conversion factor

- Natural radiation from soil: 0.04 μ Sv/h
- Ratio of 134Cs to 137Cs from FDNPP: 1:1
- Date of deposition: 2011, March 21st • wet deposition
- Conversion factor: 134Cs: $5.4 \times 10^{-6}$, 137Cs: $2.1 \times 10^{-6}$

Table. Initial deposition

<table>
<thead>
<tr>
<th>ID</th>
<th>134Cs, 137Cs [Bq/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>6</td>
<td>$1.41 \times 10^6$</td>
</tr>
<tr>
<td>7</td>
<td>$1.79 \times 10^6$</td>
</tr>
<tr>
<td>8</td>
<td>$1.31 \times 10^6$</td>
</tr>
<tr>
<td>9</td>
<td>$1.91 \times 10^6$</td>
</tr>
<tr>
<td>12</td>
<td>$1.71 \times 10^6$</td>
</tr>
<tr>
<td>13</td>
<td>$1.72 \times 10^6$</td>
</tr>
<tr>
<td>14</td>
<td>$1.23 \times 10^6$</td>
</tr>
<tr>
<td>15</td>
<td>$1.96 \times 10^6$</td>
</tr>
</tbody>
</table>
## Input of Decontamination Parameters

### Decontamination methods and parameters

<table>
<thead>
<tr>
<th>CM</th>
<th>Waste</th>
<th>Waste rate [kg/m²]</th>
<th>Depth removed [m]</th>
<th>DF</th>
<th>Team size</th>
<th>Work-rate [m²/team, hr]</th>
<th>Equipment cost [€/m²]</th>
<th>Material cost [€/m²]</th>
<th>Labour cost [€/m²]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Top soil and turf removal (mechanical)</td>
<td>soil and turf</td>
<td>30</td>
<td>0.02</td>
<td>3</td>
<td>8</td>
<td>66</td>
<td>0.09</td>
<td>0</td>
<td>5.3</td>
</tr>
<tr>
<td>(small scale)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Top soil and turf removal (mechanical)</td>
<td>soil and turf</td>
<td>30</td>
<td>0.02</td>
<td>3</td>
<td>8</td>
<td>66</td>
<td>0.09</td>
<td>0</td>
<td>5.3</td>
</tr>
<tr>
<td>(large scale)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Road surface removal</td>
<td>asphalt</td>
<td>11.2</td>
<td>0.005</td>
<td>22</td>
<td>9</td>
<td>173</td>
<td>0.2</td>
<td>0.1</td>
<td>3.9</td>
</tr>
<tr>
<td>Roof brushing</td>
<td>dust</td>
<td>3</td>
<td>–</td>
<td>1.5</td>
<td>8</td>
<td>17.5</td>
<td>0</td>
<td>0</td>
<td>10.9</td>
</tr>
</tbody>
</table>
3-2 Decontamination Strategies Settings

To compare actual decontamination operation to other decontamination strategies (in terms of radiation dose change and resource consumption)

Strategy 1: case of actual decontamination strategy (as default)

applying decontamination work such as removal of soil, cutting road surface, and brushing roofs to all mesh (ID=6,7,⋯15)

Strategy 2: case of strategy 1 without roof brushing

For evaluate different decontamination method. Despite high cost and high workloads of roof brushing, the effect is very limited, which revealed from the model project.

Strategy 3: case of strategy 2 without decontamination of ID=12

For evaluate changes of decontamination area. To see how decontamination area will affect the result, without decontamination of ID=12, where shows the least effects of decontamination from monitoring data.
3-2 Calculation results

Strategy 1 (ID=7)

Surface contamination of environmental media

Public individual dose (outdoor)

Public individual dose (indoor)

Integrated additional dose
Calculation results (to be continued)

Air dose rate at from ID=6 to ID=15 in the case of strategy 1

12

13

14

15

6

7

8

9

calculation
observed
### Comparison on the decontamination strategies

#### Table. Comparison among decontamination strategies

<table>
<thead>
<tr>
<th>Values</th>
<th>No-countermeasure</th>
<th>Strategy 1</th>
<th>Strategy 2</th>
<th>Strategy 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Exposure to public</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[man-Sv]</td>
<td>1.29</td>
<td>0.928</td>
<td>0.970</td>
<td>1.01</td>
</tr>
<tr>
<td><strong>Exposure to worker</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[man-Sv]</td>
<td>0</td>
<td>0.120</td>
<td>0.0216</td>
<td>0.0179</td>
</tr>
<tr>
<td><strong>Cost</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[€]</td>
<td>0</td>
<td>6.55 × 10^5</td>
<td>2.11 × 10^5</td>
<td>1.89 × 10^5</td>
</tr>
<tr>
<td><strong>Waste amount</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[kg]</td>
<td>0</td>
<td>2.61 × 10^6</td>
<td>2.57 × 10^6</td>
<td>2.27 × 10^6</td>
</tr>
<tr>
<td><strong>Workloads</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>[man-days]</td>
<td>0</td>
<td>943</td>
<td>166</td>
<td>141</td>
</tr>
</tbody>
</table>

※Exposure to public was calculated at the periods of three years later after initial deposition

Important to show specific numerical values

➡️ Useful to know by visualizing which parts are relatively good comparing to other
➡️ Possibility of Development of decontamination strategies reflecting local conditions
Thank you very much for your kind attention!!
Comparison on the decontamination strategies with Web-Hipre

<table>
<thead>
<tr>
<th>Goal</th>
<th>Criteria1</th>
<th>Weight</th>
<th>Criteria2</th>
<th>Weight</th>
<th>Alternatives</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Dose</td>
<td>0.5</td>
<td>Dose to worker</td>
<td>0.2</td>
<td>No-countermeasure</td>
</tr>
<tr>
<td></td>
<td>Resources</td>
<td>0.5</td>
<td>Cost</td>
<td>0.8</td>
<td>Strategy 1</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.2</td>
<td>Mass.Waste</td>
<td>0.5</td>
<td>Strategy 2</td>
</tr>
<tr>
<td></td>
<td>Overall</td>
<td>0.3</td>
<td>Effort</td>
<td>0.2</td>
<td>Strategy 3</td>
</tr>
</tbody>
</table>

Decision by Policy Maker
From results of ERMIN with considered weight of factors

Example of cost
Comparison on the decontamination strategies with Web-Hipre

The sum of the values obtained by multiplying the weight

Aspect of Radiation Dose:
No.1 is the best, but No.2 and 3 show also not much difference

Aspect of Resource Input:
Comparing No 2 and 3, No1 shows twice higher.

➔ No. 2 or 3 are effective plan in the comprehensive manner in this case

Possible to compare the several decontamination strategies from the point of view of radiation dose and resource input based on the on places, methods, and effect of decontamination.