Estimation of radioactive release resulting from Fukushima Dai-ichi NPS accident

7.23.2012

Hiroya SHIRAKI
Manager of Environmental Assessment Group
Fukushima Dai-ichi Project Team
Nuclear Power & Plant sitting Administrative Division
TOKYO ELECTRIC POWER COMPANY
1. Flowchart for Estimation

**STEP1**
- **input data**
- **weather data**

**calculation code DIANA**

- **output**
  - release rate (Bq/s)
  - 0.5 MeV-equivalent virtual particle

- **air dose rate**

**STEP2**

- Estimation of release of each nuclide
  - noble gas
  - I-131
  - Cs-134
  - Cs-137

**STEP3**

- **input data**
- **weather data**

**calculation code DIANA**

- **output**
  - Deposited amount on the land side (Bq) Cs-137

Soil sampling data obtained by Ministry of E.C.S.S&T (deposited amount) Cs-137

DIANA : Dose Information Analysis for Nuclear Accident
1.1 Fukushima-Daiichi site map
1.2 Measured air dose rate data

Measured by monitoring car in power station
1.3 Weather data & DIANA

**Weather data**
- *the wind direction & wind speed* (measured by monitoring car)
- *precipitation* (by Japan Meteorological Agency)

**DIANA**
- DIANA: Dose Information Analysis for Nuclear Accident
  - assessment domain:
    - 30km on the land side × 50km north-to-south line
    - 20km on the sea side × 50km north-to-south line
  - calculation step: 10-minutes intervals
  - release point: one point
  - Capable of assessing the air dose rate at a specified location and time by inputting the release rate of 0.5 MeV-equivalent virtual particle and weather data.
  - Capable of assessing the amount of deposition on soil at a specified location and time by inputting the release rate of the iodine and particulate nuclides and weather data.
1.4 Flowchart of the estimation for 0.5MeV-equivalent virtual particle

- Assumption of a release rate
- Calculation code (DIANA)
- Trace the measured air dose rate curve

Air dose rate data

- check

- yes
- Repeat the above estimation March 12-31
- the released of amount of 0.5 MeV-equivalent virtual particle (March 12-31)

- no
1.5 Estimation of release of each nuclide【1/2】

- Contamination of observation area are caused by deposition of iodine and cesium.
- Deposition of iodine and cesium increases the background dose rate around the observation area. (main contributors are iodine and cesium)
- The deposited iodine and particulate nuclides decay according to their half life period.
- To estimate the portion of noble gas, iodine and cesium in the plume, we varied the ratio and calculated by DIANA until we could reconstruct the curve of the measured dose rate.

![Graph showing air dose rate (μSv/h) over time. The decay curve shape depends mainly on the composition of iodine. Peaks formed by noble gas, iodine, and particulate nuclides. Background increase by cesium.]
The results of an examination of ratio of the susceptibility of the radioactive nuclides to release showed that the ratio of noble gases, iodine and cesium was 100:10:1
2.1 Result of FP release volume

<table>
<thead>
<tr>
<th></th>
<th>noble gas</th>
<th>I-131</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>500PBq</td>
<td>500PBq</td>
<td>10PBq</td>
<td>10PBq</td>
</tr>
</tbody>
</table>

Since the amount of radioactive materials that has been released into the atmosphere from April on is less than 1% of the amount released in March, the period for which the amount released into the atmosphere is estimated is set between March 12 and March 31, 2011.

- $1\text{PBq}(\text{peta Becquerel})=1,000\text{trillion Bq}=10^{15}\text{Bq}$
- The value estimated by TEPCO is rounded off to one decimal place, being a figure in Bq at the time of released.
2.2 Time variation of Amount Released

FP release volume

- **noble gas**
- **I-131**
- **Cs-137**

- PBq (noble gas I-131)
- PBq (Cs-137)

Day
2.2 Result of Investigations on FP release rate

<table>
<thead>
<tr>
<th>Day</th>
<th>FP release rate [PBq/s]</th>
</tr>
</thead>
<tbody>
<tr>
<td>12</td>
<td>1.E-15</td>
</tr>
<tr>
<td>13</td>
<td>1.E-13</td>
</tr>
<tr>
<td>14</td>
<td>1.E-11</td>
</tr>
<tr>
<td>15</td>
<td>1.E-09</td>
</tr>
<tr>
<td>16</td>
<td>1.E-07</td>
</tr>
<tr>
<td>17</td>
<td>1.E-05</td>
</tr>
<tr>
<td>18</td>
<td>1.E-03</td>
</tr>
<tr>
<td>19</td>
<td>1.E-01</td>
</tr>
<tr>
<td>20</td>
<td>1.E+00</td>
</tr>
<tr>
<td>21</td>
<td>1.E+00</td>
</tr>
<tr>
<td>22</td>
<td>1.E+00</td>
</tr>
<tr>
<td>23</td>
<td>1.E+00</td>
</tr>
<tr>
<td>24</td>
<td>1.E+00</td>
</tr>
<tr>
<td>25</td>
<td>1.E+00</td>
</tr>
<tr>
<td>26</td>
<td>1.E+00</td>
</tr>
<tr>
<td>27</td>
<td>1.E+00</td>
</tr>
<tr>
<td>28</td>
<td>1.E+00</td>
</tr>
<tr>
<td>29</td>
<td>1.E+00</td>
</tr>
<tr>
<td>30</td>
<td>1.E+00</td>
</tr>
<tr>
<td>31</td>
<td>1.E+00</td>
</tr>
</tbody>
</table>

Graph showing FP release rate over time with different noble gases.
### 3. FP release volume  
【vent & explosion】

<table>
<thead>
<tr>
<th>unit</th>
<th>time</th>
<th>event</th>
<th>release volume (PBq)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td>noble gas</td>
</tr>
<tr>
<td>1</td>
<td>3.12 14:00～</td>
<td>vent</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>3.12 15:36</td>
<td>explosion</td>
<td>10</td>
</tr>
<tr>
<td>3</td>
<td>3.13 09:00～</td>
<td>vent</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>3.13 12:00～</td>
<td>vent</td>
<td>&lt;0.04</td>
</tr>
<tr>
<td></td>
<td>3.13 20:00～</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.14 06:00～</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.15 16:00～</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.16 02:00</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.17 21:00</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.18 05:00～</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.20 11:00</td>
<td>vent</td>
<td>&lt;0.003</td>
</tr>
<tr>
<td></td>
<td>3.14 11:01</td>
<td>explosion</td>
<td>1</td>
</tr>
</tbody>
</table>

**Sub total**  
vent & explosion: 20 4 0.09 0.06

**Total**  
between March 12 and March 31: 500 500 10 10
4. Deposition Cs-137

Deposition Cs-137
PBq / (50km × 30km)

<table>
<thead>
<tr>
<th>Survey Data</th>
<th>1PBq</th>
</tr>
</thead>
<tbody>
<tr>
<td>DIANA estimation</td>
<td>1PBq</td>
</tr>
</tbody>
</table>

Soil sampling data & range of DIANA estimation

- **Deposition Cs-137**
  - PBq / (50km × 30km)

- **Survey Data**: 1PBq
- **DIANA estimation**: 1PBq

---

- **Cs - 137**
  - 沈着量 (Bq / m²)
  - 3000k <
  - 1000k - 3000k
  - 600k - 1000k
  - 300k - 600k
  - 100k - 300k
  - 60k - 100k
  - 30k - 60k
  - 10k - 30k
  - ≤ 10k

- 测定結果が
  - 得られていない範囲

※10k Bq = 1万8k Bq (ベクレル)

---

- **range of DIANA estimation**
  - 30km
  - 50km

---

- **Soil sampling data & range of DIANA estimation**
### 5. Estimation results of other Organization

<table>
<thead>
<tr>
<th>Organization</th>
<th>noble gas</th>
<th>I-131</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>TEPCO 5.24.2012</td>
<td>500</td>
<td>500</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>JAEA 8.22.2011</td>
<td>-</td>
<td>130</td>
<td>-</td>
<td>11</td>
</tr>
<tr>
<td>JAEA 3.6.2012</td>
<td>-</td>
<td>120</td>
<td>-</td>
<td>9</td>
</tr>
<tr>
<td>NISA 4.12.2011</td>
<td>-</td>
<td>130</td>
<td>-</td>
<td>6.1</td>
</tr>
<tr>
<td>NISA 6.6.2011</td>
<td>-</td>
<td>160</td>
<td>18</td>
<td>15</td>
</tr>
<tr>
<td>NISA 2.16.2012</td>
<td>-</td>
<td>150</td>
<td>-</td>
<td>8.2</td>
</tr>
<tr>
<td>IRSN</td>
<td>2000</td>
<td>200</td>
<td>30</td>
<td></td>
</tr>
<tr>
<td>Chernobyl NPP</td>
<td>6500</td>
<td>1800</td>
<td>-</td>
<td>85</td>
</tr>
</tbody>
</table>

JAEA : Japan Atomic Energy Agency  
NISA : Nuclear and Industrial Safety Agency  
IRSN : Institut de Radioprotection et de Sûreté Nucléaire
6. Cause of Contamination of NW region 【1/3】

- Air dose rate showed rapid increase around 10:00 am on 3/15 but there were no plant operation like venting.
- This picture shows the steam release from Unit 2 around 10:00 am on 3/15.
6. Cause of Contamination of NW region 【2/3】

These pictures indicate that the plume released from Unit 2 on 3/15 located NW region from evening to midnight.
According to the weather radar, around NW region it was raining from evening to midnight on 3/15.

We concluded the main cause of the contamination of NW region was the uncontrolled release from Unit 2.
7. Summary & Uncertainty

- Cs-137
  - Almost equivalent to those announced by other institutions.

- I-131
  - Our result ended up being three times greater than those of other institutions.
  - A factor contributing to this difference is thought to be that the ratio of susceptibility of the radioactive nuclides to release was assumed to be a fixed ratio.

- From changes in the air dose rate data at one location within the power station premises at each time during the assessment period, DIANA was used to assess the release rate such that the air dose rate data was reproduced.

- Data was used for 16 directions as measured by monitoring cars.

- In light of DIANA specifications, the location of release at each time during the assessment period is limited to one location.

- Data from nearby AMEDAS observation points was used.
8.1 Case study “uncertainty of estimation”

Sorting according to Nuclide

Ratio of the susceptibility of radioactive nuclides to release

Ratio of radioactivity rate (iodine and cesium)

Reference

“Journal of Environmental Radioactivity Volume 112, October 2012, Pages 141-154”

Atmospheric discharge and dispersion of radio nuclides during the Fukushima Dai-ichi Nuclear Power Plant accident. Part II: verification of the source term and analysis of regional-scale atmospheric dispersion

JAEA Hiroaki Terada, Genki Katata, Masamichi Chino, Haruyasu Nagai

Table 2
Release period, release duration, $^{131}$I release rate, $^{131}$I/$^{137}$Cs radioactivity ratio, release height, and references in which each source term was estimated or refined, for the period between 5 JST on March 12 and 0 JST on May 1, 2011. The values in parentheses are from Chino et al. (2011).
### 8.2 Result of Case study

<table>
<thead>
<tr>
<th></th>
<th>Noble gas : iodine&lt;sup&gt;note1&lt;/sup&gt;</th>
<th>Noble gas</th>
<th>I-131</th>
<th>Cs-134</th>
<th>Cs-137</th>
</tr>
</thead>
<tbody>
<tr>
<td>Result (5.24.2012) &lt;sup&gt;note2&lt;/sup&gt;</td>
<td>100:10</td>
<td>500</td>
<td>500</td>
<td>10</td>
<td>10</td>
</tr>
<tr>
<td>JAEA’s ratio application</td>
<td>100:10</td>
<td>500</td>
<td>400</td>
<td>40</td>
<td>30</td>
</tr>
<tr>
<td></td>
<td>100:1</td>
<td>700</td>
<td>400</td>
<td>30</td>
<td>20</td>
</tr>
</tbody>
</table>

<sup>note1</sup>: ratio of the susceptibility of radioactive nuclides to release
<sup>note2</sup>: The estimation result (P8) pressed by TEPCO at 5.24.2012

#### Estimation of I-131
- Estimation of the results of these cases (JAEA’s ratio application) was not the result of greatly reduced compared with previous results of the evaluation of the case.

#### Remaining uncertainty
- **16 directions** as measured by monitoring cars
- **DIANA specifications**