Management and Evaluation of the Forest Fire Situation in the Exclusion Zone and Zone of Unconditional (Mandatory) Resettlement

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Density of 137Cs Contamination
kBq/m²

1 1.5 2 2.5 3

1985
Total Contamination of territory with 137Cs
(global + chornobyl)
kBq/m²

1986
Scale of density of contamination by 137Cs
1st

> 555 kBq/m²

Development of the special regime for forestry.
Limitation of the working time

2nd-

370-555 kBq/m²

Limitation of utilization of wood for the people’s needs

2nd-

370-259 kBq/m²

Not allowed to use wood as the fuel and to manufacture the domestic goods and facilities for the foodstuff storing

2nd-

185-259 kBq/m²

Limitation of utilization of the fuel and hungry wood and meat of the wild animals. Prohibition to hunting roe

3th-

74-185 kBq/m²

Prohibition of consumption of the wild berries and mushrooms. Limitation of utilization of the medical plants and wild animals

3th-

37-74 kBq/m²

Limitation of utilization of the mushrooms, wild berries and some medical plants

<37 kBq/m²

Utilization of the forest products without limitation
Crowded Forest, American West
(Yakama Reservation)
AREA BURNED ANNUALLY BY WILDFIRES IN THE WESTERN UNITED STATES, 1940-1994

MILLIONS OF ACRES

YEAR

1940 1960 1980 1992
Scotts pine forest in Chernobyl radioactive zone, Ukraine. These forests are overly crowded and need thinning to reduce fire danger.
Radioisotopes found in Chernobyl Exclusion Zone Forests

**90 Sr** — common in CEZ, high dose coeff. for external exposure pathways;  
Half life: 20-28 years

**137 Cs** — common in CEZ, high dose coeff. for external exposure pathways;  
Half life: 30 years

**154Eu** — high dose coeff. for external exposure pathways;  
Half life: 9 years

**238Pu, 239Pu, 240Pu** — high dose coefficients for internal exposure pathways;  
Half life: 6,500 – 24,000 years

**241Am** — high dose coefficients for internal exposure pathways.  
Half life—432 years
Table 1. Estimated fuel component radionuclides in soil and vegetation of the 30-km Chernobyl exclusion zone in Ukraine in 2000 and 2010. Fuel component radionuclides in 2000 in upper 30-cm soil layer outside the ChNPP industrial site, excluding the activity located in the radioactive waste storages and in the cooling pond are from Kashparov et al. (2003). Estimates of concentration factors (ratio of radionuclides in vegetation and litter to soil) in forest and grasslands were derived from Lux et al. (1995), Sokolik et al. (2004), Yoschenko et al. (2006).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Radionuclide Inventory (Bq)</th>
<th>Ratio Combustible/Soil</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Soil in 2000</td>
<td>Soil in 2010</td>
</tr>
<tr>
<td>$^{90}$Sr</td>
<td>7.7E+14</td>
<td>6.1E+14</td>
</tr>
<tr>
<td>$^{137}$Cs</td>
<td>2.8E+15</td>
<td>2.2E+15</td>
</tr>
<tr>
<td>$^{154}$Eu</td>
<td>1.4E+13</td>
<td>6.4E+12</td>
</tr>
<tr>
<td>$^{238}$Pu</td>
<td>7.2E+12</td>
<td>6.7E+12</td>
</tr>
<tr>
<td>$^{239,240}$Pu</td>
<td>1.5E+13</td>
<td>1.5E+13</td>
</tr>
<tr>
<td>$^{241}$Am</td>
<td>1.8E+13</td>
<td>1.8E+13</td>
</tr>
</tbody>
</table>
Схема локалізації осередків пожеж в Київській та Житомирській областях 8 травня 2003 року

Фрагмент космічного звіму із супутника NOAA 08.05.2003, 18-30, наданого Українським центром менеджменту землі та ресурсів
Ukrainian Forest Service Inventory

LMS Platform
The Landscape Management System (LMS, McCarter et al. 1998; Oliver et al. 2009) provides a variety of tools for examining management consequences on forested landscapes by analyzing each stand and linking results at the landscape level. (See http://Landscapemanagementsystem.org)

FVS Growth Model
The Forest Vegetation Simulator (FVS, Dixon 2002, Wykoff et al 1982) - Lake States (LS) Variant was used for the forest simulations in this analysis.

FVS Calibration
Aaron and Mykhaylo provided analysis showing differences in expected growth and the growth model used. For this example analysis the performance of red pine and scotch pine in the Lake States variant of FVS

Ukraine Fire Risk Classification Rules
(See later slide)

United States Forest Service, FVS, FFE, Crowning Index
(See later slide)

GIS
Figure 4. Google Earth image showing Ukraine Fire Risk Classification on Chornobyl landscape. Note area to right of classified area which appears to be a large open area possibly from burns.
Figure 1. Chornobyl area showing various vegetation types in the area.
Ukraine Fire Risk classes.

2021>>
1996

2021,
with management

2021,
no management

2021,
Before thinning.
Immediately after thinning.
Equipment that can do the thinning with minimal exposure of people to radioactive dust
MODIS satellite image of fire locations (red dots) and smoke in Ukraine and its neighboring countries, April 16, 2006.
Steps in Analysis Process

• Prepare model in consultation with experts in various components
• Obtained lists of expert reviewers
• Sent out requests for review
• Receiving reviews back (requested CV, cover letter, and review)
• Will publish reviews with Report (perhaps amend report according to reviewers comments)
Wildfire in the Chernobyl Exclusion Zone: A Worst Case Scenario

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Andrew Niccolai, Ph.D.

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Sergiv Zibtsev, Ph.D.
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Volodymyr Gulidov

December 11, 2010

ACKNOWLEDGEMENTS
We thank Dr. V.A. Kashparov and Dr. V.I. Yoschenko of the Ukrainian Institute of Agricultural Radiology, and Dr. Y. Goksu for critically reviewing previous drafts of this report and Dr. Yeter Goksu for her advice throughout the project and during preparation of the report. This report would not have been possible without the support of Dr. Dmytro Melnychuk, Rector, Rector, National University of Life and Environmental Sciences of Ukraine (NUBiP of Ukraine) and Mr. George Chopivsky, Jr., President, Chopivsky Family Foundation
This is our current working model for assessing impacts of discharges from radioactive substances to the environment.
Four Linked Models

1. Source

2. Transport

3. Exposure

4. Cancer & Death

0 km  25 km  50 km  100 km  150 km
Схема локалізації осередків пожеж в Київській та Житомирській областях 8 травня 2003 року.

Фрагмент космічного звіму із супутника NOAA 08.05.2003, 18-30, наданого Українським центром менеджменту землі та ресурсів.
\[
C_A = \frac{P_p F Q_i}{u_a}
\]  

where

- \( C_A \) is the ground level air concentration at downwind distance \( x \) in sector \( p \) (Bq/m\(^3\)) \(^1\),
- \( P_p \) is the fraction of time per event that the wind blows toward the target population,
- \( F \) is the Gaussian diffusion factor \(^2\) appropriate for a given release height \(^3\) and downwind distance \( x \) (m\(^{-2}\)),
- \( Q_i \) is the average discharge rate per event for radionuclide \( i \) (Bq/s),
- \( u_a \) is the geometric wind speed average at the area of release representative of the duration of the event (m/s).

\(^1\) As formulated in the IAEA model, \( C_A \) at a given distance is independent of deposition velocity. Thus, the model does not take into account depletion of the plume due to deposition to the ground.

\(^2\) The Gaussian diffusion factor formula is given on page 18 of the IAEA SRS No. 19. It assumes a neutral atmospheric stability class (Pasquill–Gifford stability class D).

\(^3\) Emission height was assumed to be 0 m. This gives the highest possible ground level air concentration (and hence, highest level of contamination). In an actual cataclysmic fire one would expect the emission height to be 10s to 100s of meters. This would have the effect of spreading the contamination over a larger area and making the effects in any one location less serious. Thus, assuming a release height of 0 m is conservative.
Immersion

Inhalation

Ground Exposure

Ingestion
Table 4. Element specific transfer factors for terrestrial foods for screening purposes (IAEA 2001).

<table>
<thead>
<tr>
<th>Element</th>
<th>Forage (Bq/ kg plant dry weight)/ (Bq/kg soil dry weight)</th>
<th>Crops (Bq/ kg plant fresh weight)/ (Bq/kg soil dry weight)</th>
<th>Milk (d/L)</th>
<th>Meat (d/kg)</th>
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<td>0.3</td>
<td>0.003</td>
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<td>Cs</td>
<td>1</td>
<td>0.04</td>
<td>0.01</td>
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</tr>
<tr>
<td>Eu</td>
<td>0.1</td>
<td>2.0E-03</td>
<td>6.0E-05</td>
<td>2.0E-03</td>
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<tr>
<td>Pu</td>
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<td>3.0E-06</td>
<td>2.0E-04</td>
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<tr>
<td>Am</td>
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<td>2.0E-03</td>
<td>2.0E-05</td>
<td>1.0E-04</td>
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Table 2. Effective immersion, surface, inhalation, and ingestion dose coefficients for various radioisotopes (IAEA 2001).

<table>
<thead>
<tr>
<th>Radionuclide</th>
<th>Immersion (Sv/a per Bq/m³)</th>
<th>Surface (Sv/a per Bq/m²)</th>
<th>Inhalation (Sv/a per Bq/m³)</th>
<th>Ingestion (Sv/a per Bq/kg)</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Adult</td>
<td>Infant</td>
<td>Adult</td>
<td>Infant</td>
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<td>⁹⁰Sr</td>
<td>3.1E-09</td>
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<td>¹³⁷Cs</td>
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<td>¹⁵⁴Eu</td>
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<td>Ground Exposure (Sv/a)</td>
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<tr>
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<tr>
<td>$^{241}$Am</td>
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<td><strong>Total</strong></td>
<td>25</td>
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<td>7.2E-04</td>
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<td>150</td>
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<td>1.4E-04</td>
<td>1.2E-04</td>
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<td>Exposure (milliSv/year)</td>
<td>Distance from Fire Center (km)</td>
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<td></td>
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<td>------------------------</td>
<td>-------------------------------</td>
<td></td>
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<td>Ground Exposure</td>
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<td>Adult</td>
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<td>4.8</td>
<td>1.7</td>
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<td></td>
<td>Infant</td>
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<td>Adult</td>
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<td>6.2</td>
<td>2.1</td>
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<td></td>
<td>Infant</td>
<td>27.0</td>
<td>9.4</td>
<td>3.3</td>
</tr>
</tbody>
</table>

Limiting Time Outdoors
- Adult: 2.0 milliSv/first 2 weeks
- Children: 1.0 milliSv/first 2 weeks
Evacuation done (Ukraine): 50.0 milliSv/first 2 weeks
Resettlement dose (Ukraine): 50.0 milliSv/year
Limiting food consumption: 1.0 internal milliSv/year

### Graph: Radiation Absorbed by a Person

The graph compares various sources of radiation exposure, including different activities and locations, with a focus on milliSv. The categories include:
- Radiation from granite in U.S. Capital Building (per year)
- Mamogram
- New York-Tokyo flights, airline crew (annual)
- Permissible dose to radiation workers (annual, 5-year)
- Permissible dose to radiation workers (annual, 1-year)
- Background radiation in parts of world (per year)
- Smoking 1.5 packs/day (per year)
- Smoking 9 packs/day (per year)
- Smoking 15 packs/day (per year)
- Revised permissible dose to Fukushima workers (one-year)
- Relocation threshold after Chernobyl (lifetime)
- Nausea (one-day dose)
- Maximum recr. For volunteers saving lives
- Burns symptoms, hemorrhaging, possible death (one-day dose)
- Nervous system impairment, death (one-day dose)
- Maximum dose to Chernobyl after explosion (per hour)

The x-axis represents the radiation levels, while the y-axis shows the distance from the fire center.
The analysis showed that the estimated exposure of populations 25 or more kilometers from the source of the fire through inhalation, immersion, and surface exposure pathways is below the critical thresholds that would require evacuations by greater than an order of magnitude.

On the other hand, the potential dosage derived from the consumption of contaminated foodstuffs could exceed acceptable levels set by the Ukrainian government—a prevented internal irradiation dose exceeding 5 mSv or a prevented average annual dose exceeding 1 mSv. For both adults and infants these levels could be almost met or exceeded by consuming food produced at distances as great as 150 km from the center of the CEZ. These highest levels of contamination would occur directly along the trace of the plume. As one moved away from the trace, contamination levels would decline, so the actual amount of agricultural land that would need to be taken out of production would be limited.
From an epidemiological standpoint, the worst case scenario would be if the trace of the plume intersected with a major population center, such as Kiev. If we assume:

1) the entire population of Kiev (2.7 million) was exposed to the trace;
2) the population had a sex ratio of 1:1 at the time of the fire; and
3) the average age of the population was 20 at the time of the fire; and
4) residents successfully avoided exposure through ingestion; then we would expect 168 additional cancers to be diagnosed over the lifetime of the residents based on the exposure during the first year after the fire. We would expect 81 additional cancer deaths to occur.
Steps in Analysis Process

- Prepare model in consultation with experts in various components
- Obtained lists of expert reviewers
- Sent out requests for review
- Receiving reviews back (requested CV, cover letter, and review)
- Will publish reviews with Report (perhaps amend report according to reviewers comments)
- (May consider submission to journal)