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System Perspective in Environmental Remediation of Lands Contaminated from the Fukushima Accident

Robert L. Sindelar, Embassy Science Fellow to Japan 2013

*WMS Panel: "Technology Support and Implementation for Clean Up of Fukushima Daiichi NPP"
March 6, 2014*

Topics

- **Fukushima Daiichi Accident Clean-up**
 - On-site remediation: Fukushima Daiichi Nuclear Power Station (NPS) site
 - Off-site remediation: Outside NPS fence
- **Remediation of a Large Land Area with High Contamination**
 - Remediation System Elements
 - Selected ESF Report Observations and Recommendations



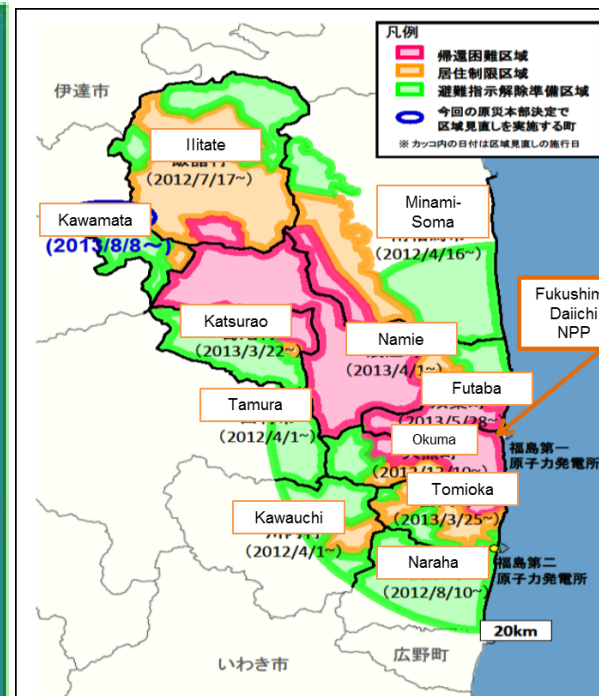
Report from the ESF Assignment

- sets a framework,
- provides status, and
- recommends improvements for remediation of land with surface contamination

Off-Site Contamination Areas

1 mSv = 100 mrem
 0.23 μ Sv/hour \rightarrow 1 mSv/yr

Contamination in Fukushima,
 Iwate, Miyagi, Ibaraki,
 Tochigi, Gunma, Saitama, and
 Chiba prefectures

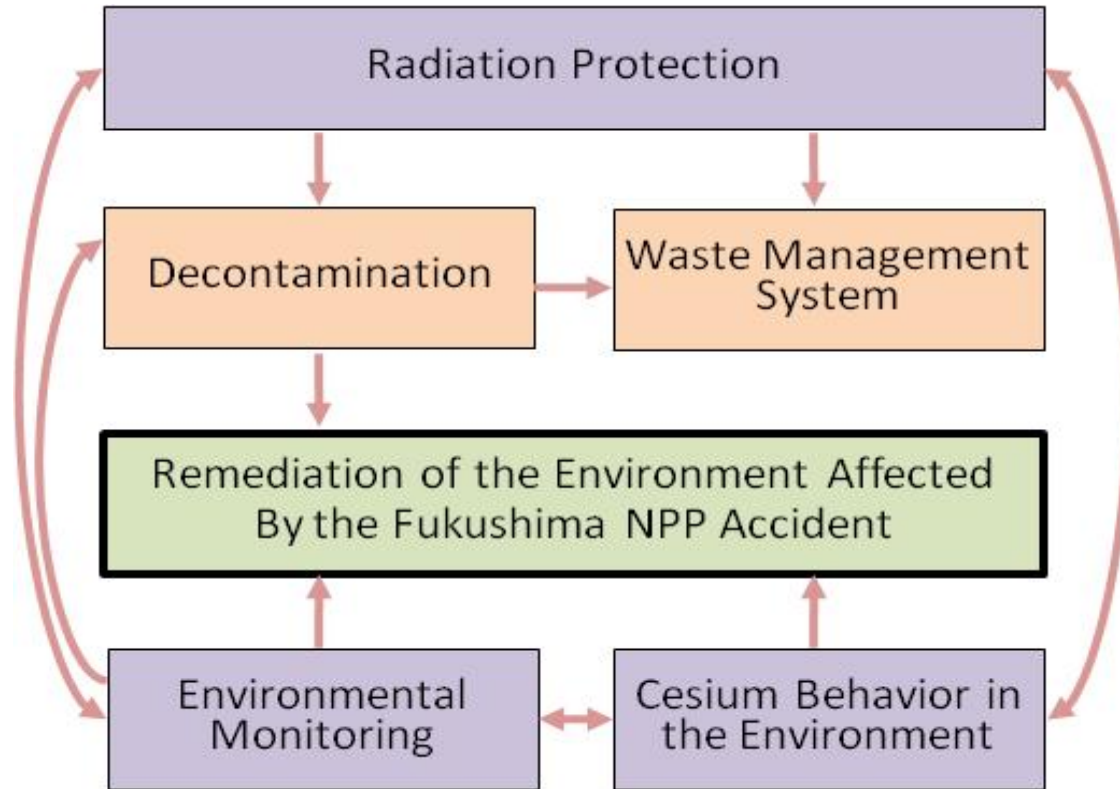


Special Decontamination Area (in red)

- Less than 20 mSv/year
- 20 to 50 mSv/year
- > 50 mSv/year

- Area 1: <20mSv/yr**
Evacuation orders are ready to be lifted:
- Area 2: 20 – 50 mSv/yr**
Residents are not permitted to live:
- Area 3: >50 mSv/yr**
Residents will have difficulties in returning for a long time:

Systems Perspective for Fukushima Offsite Remediation



Program Elements for an Environmental Remediation System for a Populated Region Contaminated by Cesium



Surfaces to be Decontaminated

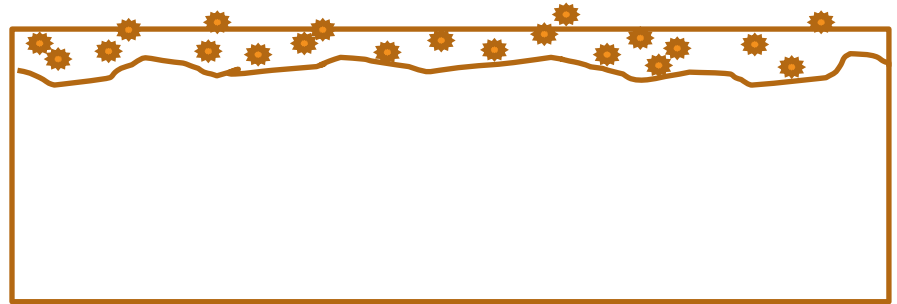
- Roads (various materials and designs)
- Soils (agricultural soils, playgrounds)
- Grassy fields
- Home lawns and landscapes
- Building structures (various materials and designs)
- Roofs (various materials and designs)
- Forests



Radioactive materials settled on soil, vegetation, and buildings



Radioactive materials consolidated and shielded



Concept of surface contaminated with cesium



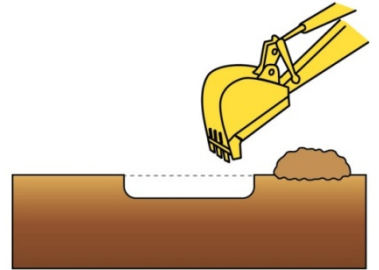
Decontamination Technologies - Present Methods in Use

- Buildings – water spray, wipes
- Roofs – water spray, wipes
- Roads – shot blast, CO₂, high pressure water spray (15 Mpa)
- Fields – cut grass
- Soils (farmland) – mixing soil or removal
- Forests – remove litter, fell trees, natural attenuation
- Advanced technologies investigated (e.g. soil particle separation), few adopted
- Methods listed in GOJ-MOE Decontamination Guidelines and in GOJ-MOE Common Specifications

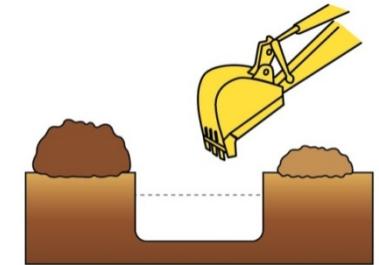
Contaminated soil surface



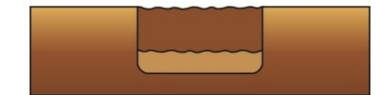
1) Dig out about 10 cm of surface soil.



2) Dig out about 20 cm of lower layer soil.



3) Place the surface soil at the bottom and cover it with the lower layer soil.



Example: Air dose rate reduction over soil
(from GOJ-MOE Decontamination Guidelines)





Wiping off rooftop and walls



Wiping off a gutter



High pressure water cleaning of a drain pipe



High pressure water cleaning of paved road



Mowing and removal of sludge



Removal of crushed stones and topsoil, and cover with clean soil

Before & After the Decontamination Work



Decontamination Effectiveness - Examples



Roads

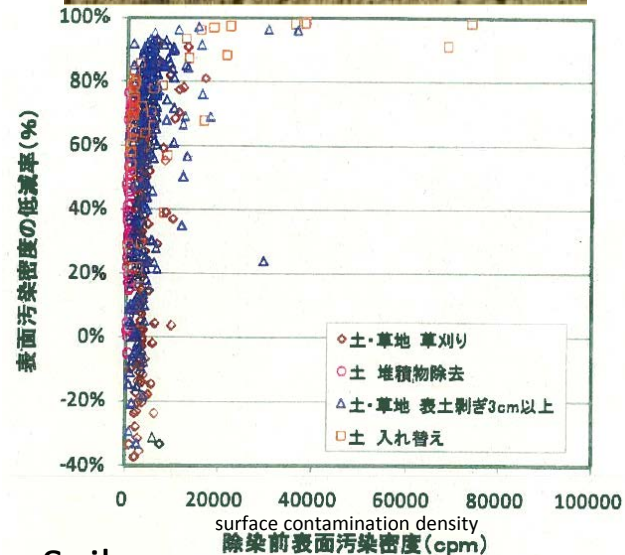
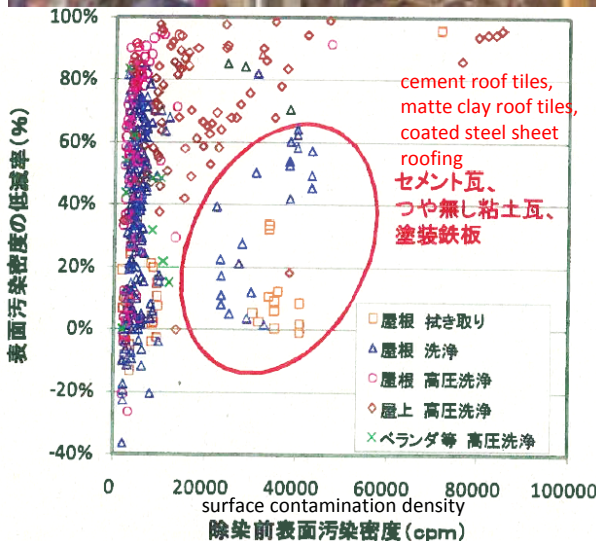
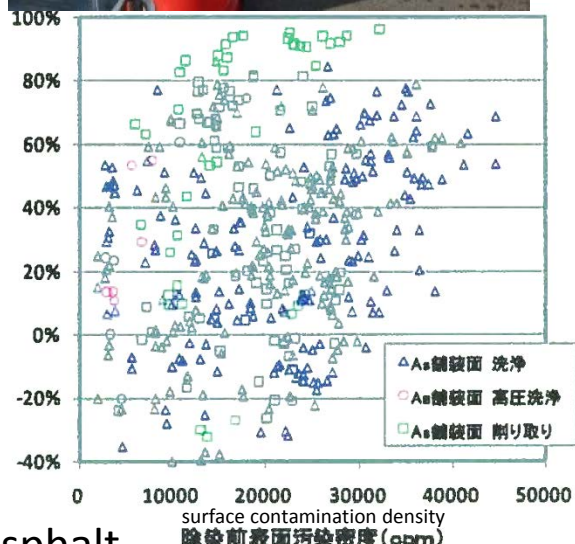


Roofs



Subsoil stripping

Soils



Asphalt Roads

- △ As舗装面 洗浄 Paved surface of roads: washing
- As舗装面 高圧洗浄 Paved surface of roads: high-pressure water washing
- As舗装面 削り取り Paved surface of roads: scraping away

Roofs

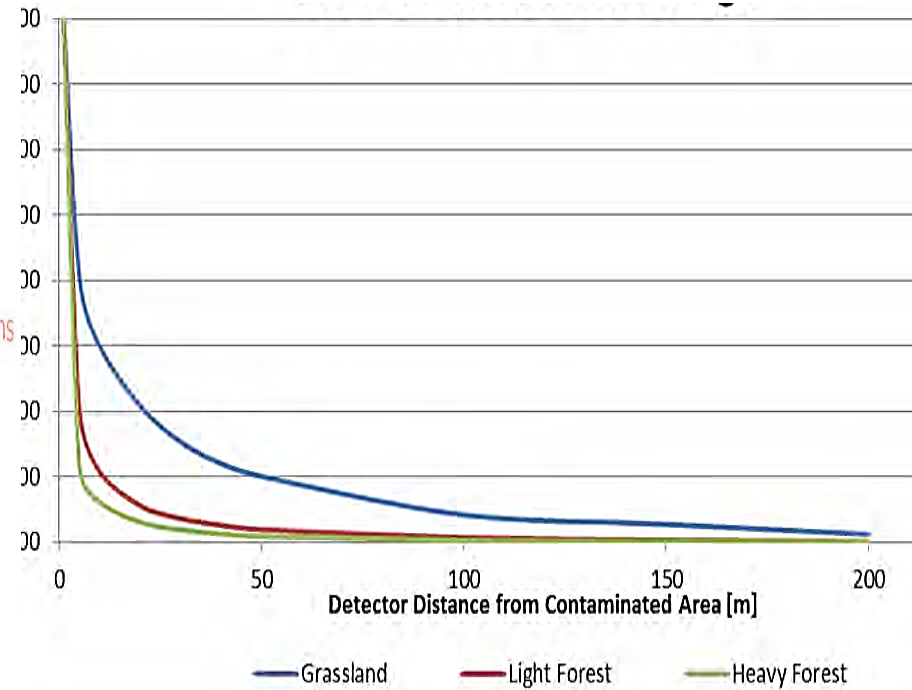
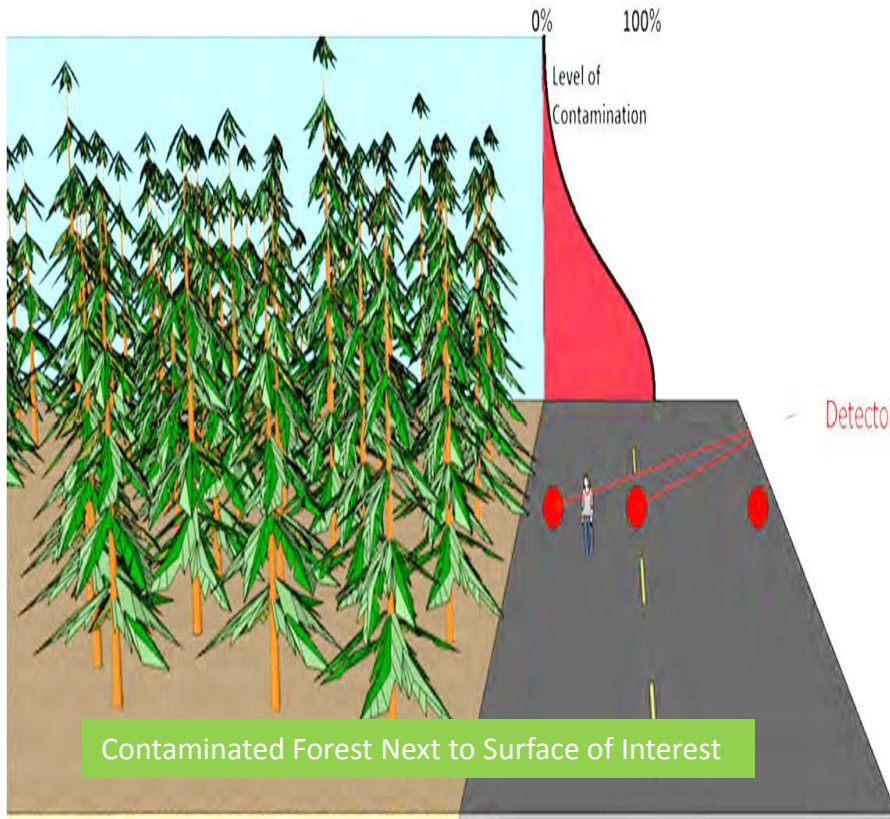
- 屋根 拭き取り Roofs: wiping
- △ 屋根 洗浄 Roofs: washing/cleaning
- 屋根 高圧洗浄 Roofs: high-pressure water washing
- ◇ 屋上 高圧洗浄 Rooftops: high-pressure water washing
- × ベランダ等 高圧洗浄 Balconies: high-pressure water washing

Soils

- ◇ 土・草地 草刈り soil/grass field: cut grass (mowing)
- 土 堆積物除去 Soil: deposit removal
- △ 土・草地 表土剥ぎ3cm以上 soil/grass field: strip away of topsoil more than 3cm
- 土 入れ替え Remove soil and replace w/new



Need for Collimated Detection – Cesium-137 Contamination



Dose Rate Contribution from Contaminated Surroundings (C. Verst, SRNL)

$$\text{Decontamination Effectiveness} = \left[1 - \left(\frac{\text{Count Rate After Decontamination}}{\text{Count Rate Before Decontamination}} \right) \right] \times 100$$



Drivers to develop advanced decontamination are to:

- Leave the surface essentially intact
- Improve decontamination effectiveness
- Achieve decontamination more quickly than by present methods
- Achieve decontamination more cost-effectively than by present methods*

*Include waste handling, transportation, storage, and disposal costs



Advanced Decontamination – Model Project Examples

Advanced decontamination methods have been investigated (with JAEA-led and MOE-led projects conducted by vendors)

| Decontamination target | Method | Features | No. | Implementer (contractor) | |
|--------------------------------------------|----------------------------------|----------------------------------------------------------|-----|------------------------------------------------|----------------------------------|
| Soil | Heat treatment | Reaction acceleration agent | 1 | Taiheiyo Cement Corporation | |
| | Separation | Pump separation | 2 | ROHTO Pharmaceutical Co., Ltd. | |
| | | Wet separation | | 3 | Takenaka Corporation |
| | | | | 4 | Kumagai Gumi Co., Ltd. |
| | | | | 5 | Hitachi Plant Technologies, Ltd. |
| | | | | 6 | Konoike Construction Co., Ltd. |
| | | | | 7 | Sato Kogyo Co., Ltd. |
| | Chemical treatment | Organic acid treatment | 8 | Toshiba Corporation | |
| Sewage Sludge | Elution | Organic reagent treatment | 9 | Nippon Steel Engineering Co., Ltd. | |
| Parks, roads and buildings | Cutting and stripping | Stripping paint | 10 | Shiga Toso Co. Ltd. | |
| | Special water-based washing | Nano-bubble water | 11 | Kyoto University | |
| | | Molecular cluster ozone water | 12 | Nature's Company | |
| | High-pressure water jet washing | Ultra-high pressure (280 MPa) | 13 | KICTEC Incorporated | |
| | Blasting and stripping | Wet blasting | 14 | Macoho Co., Ltd. | |
| Tsunami debris | Washing | Washing with water | 15 | Toda Corporation | |
| | | Dry ice cleaning | 16 | Kantechs Co., Ltd. | |
| Reduction of volume of plants and cow dung | Conversion into manure | 100°C or higher | 17 | Japan Aerospace Exploration Agency | |
| | | 50-60°C | 18 | Mikuniya Corporation | |
| Water | Sorption | Zeolite blocks | 19 | MAEDA Corporation | |
| | | Iron ferrocyanide | 20 | Tokyo Institute of Technology | |
| Woodland and timber | Stripping and solidification | Stripping and cement-based solidification | 21 | Taisei Corporation | |
| | Washing | Washing with water and incineration | 22 | Koriyama Chip Industry Co., Ltd. | |
| | | High-pressure water jet washing and water treatment | 23 | Neonite Corporation | |
| | Thinning | Focus on air dose rates | 24 | Fukushima Prefectural Forestry Research Center | |
| | Undergrowth clearing & stripping | Improving efficiencies of forest decontamination methods | 25 | Obayashi Corporation | |

<http://fukushima.jaea.go.jp/english/deconfamination/index.html>

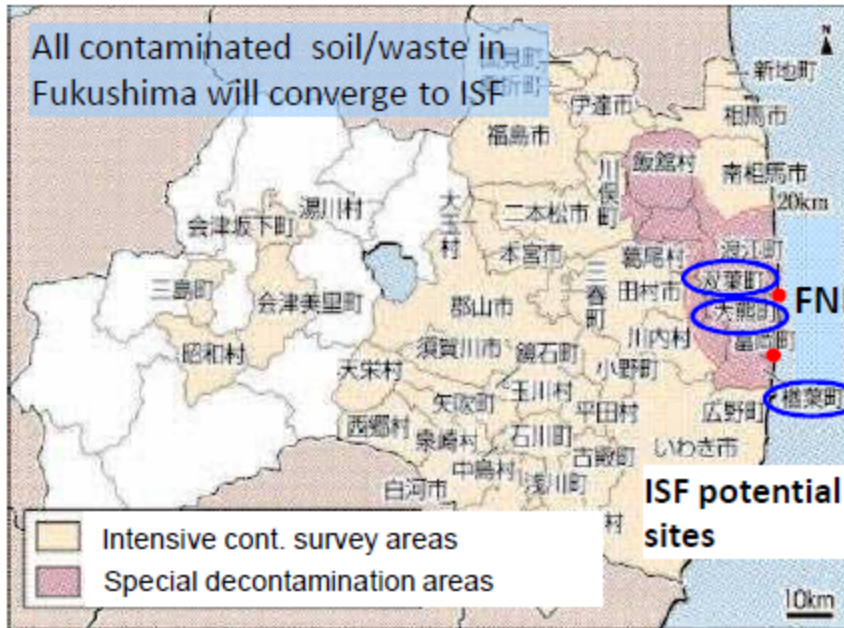


Waste Management

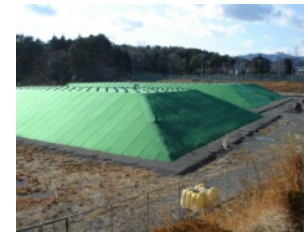
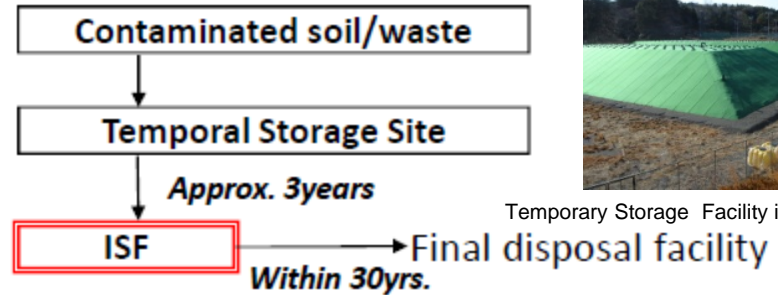
- Waste management (transportation, storage, disposal) is primary challenge for off-site remediation
- ~15 - 28 million m³ waste destined for the Interim Storage Facilities in FP



On-site Storage in Naraha Town



* FNP=Fukushima Dai-ich Nuclear Power Plant



Temporary Storage Facility in Okuma Town

ISF

- ✓ Soil and waste generated in **Fukushima Pref. only**
- ✓ Maximum effort to start operation **within approx. 3years (=beginning of 2015)**
- ✓ Final disposal facility placed **outside Fukushima within 30years.**

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Waste management overview (<http://www.env.go.jp/en/focus/docs/files/20121128-58.pdf>)