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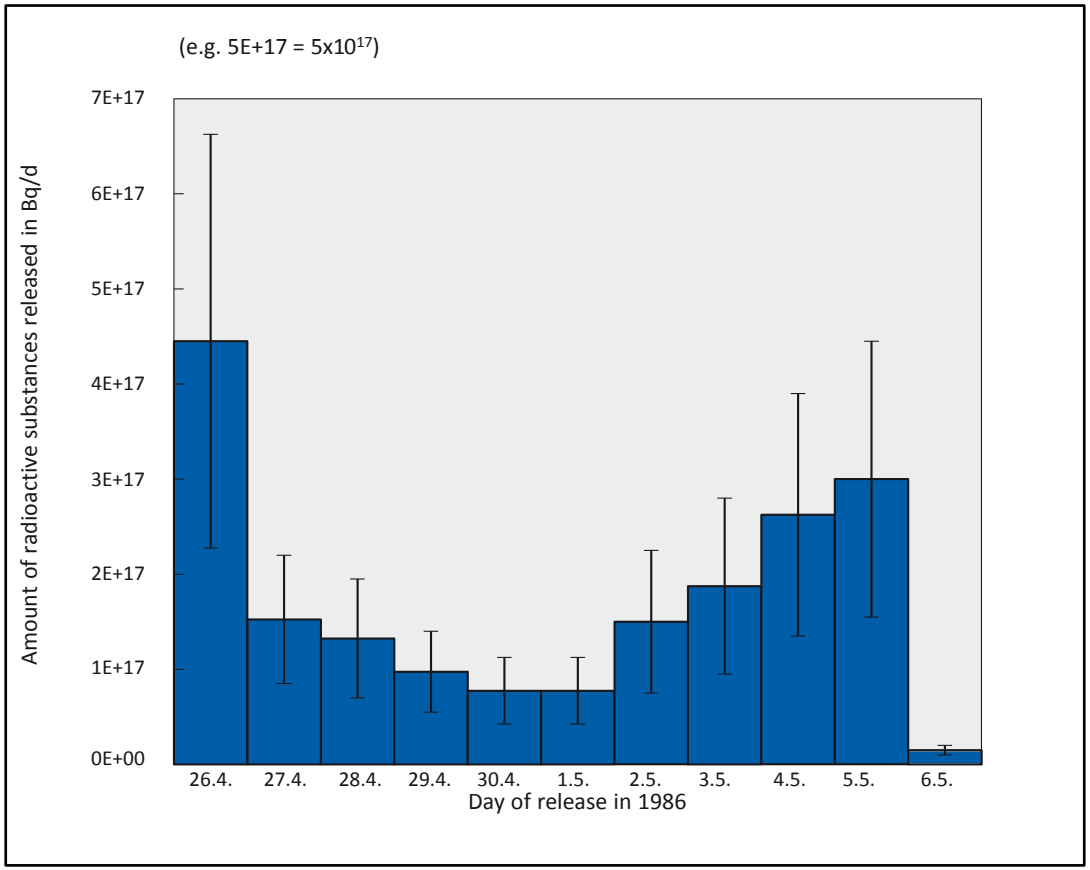
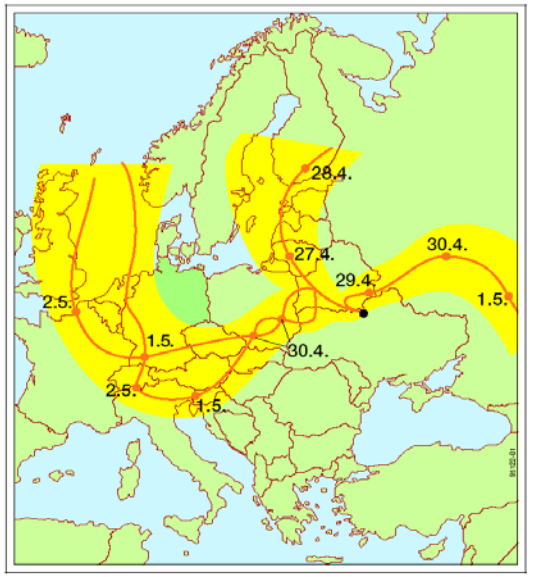
Radiological Situation at the Chernobyl Shelter Site Thirty Years after the Accident

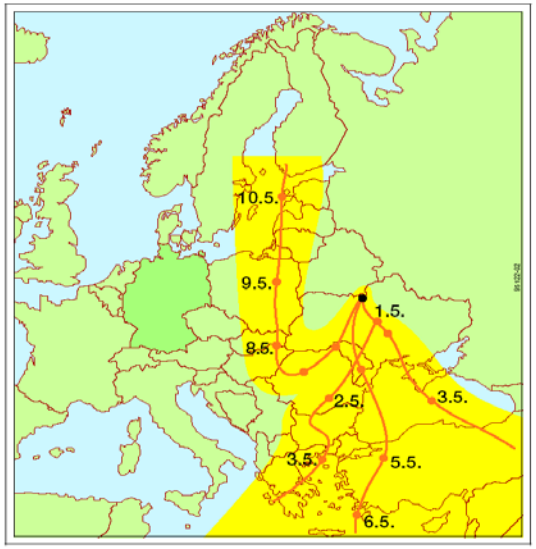
Radioactive Releases after the Chernobyl Accident

- Chernobyl NPP site
  - 0,5 % of the spent fuel inventory
- Near region of the 30 km zone
  - 1,5 % of the spent fuel inventory
- Far regions in Europa
  - 1,5 % as airborne dispersion

Releases
27.04. - 02.05.86
and
02.05. -10.05.86

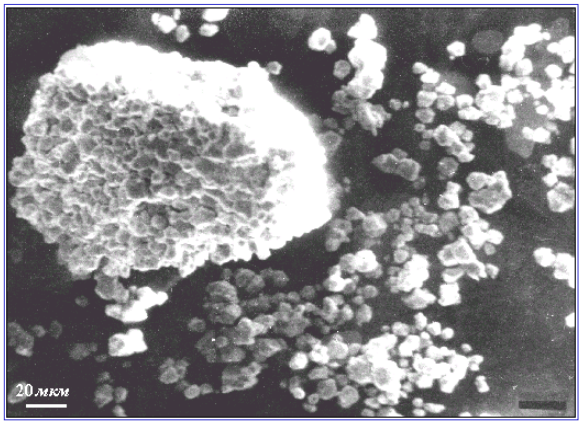






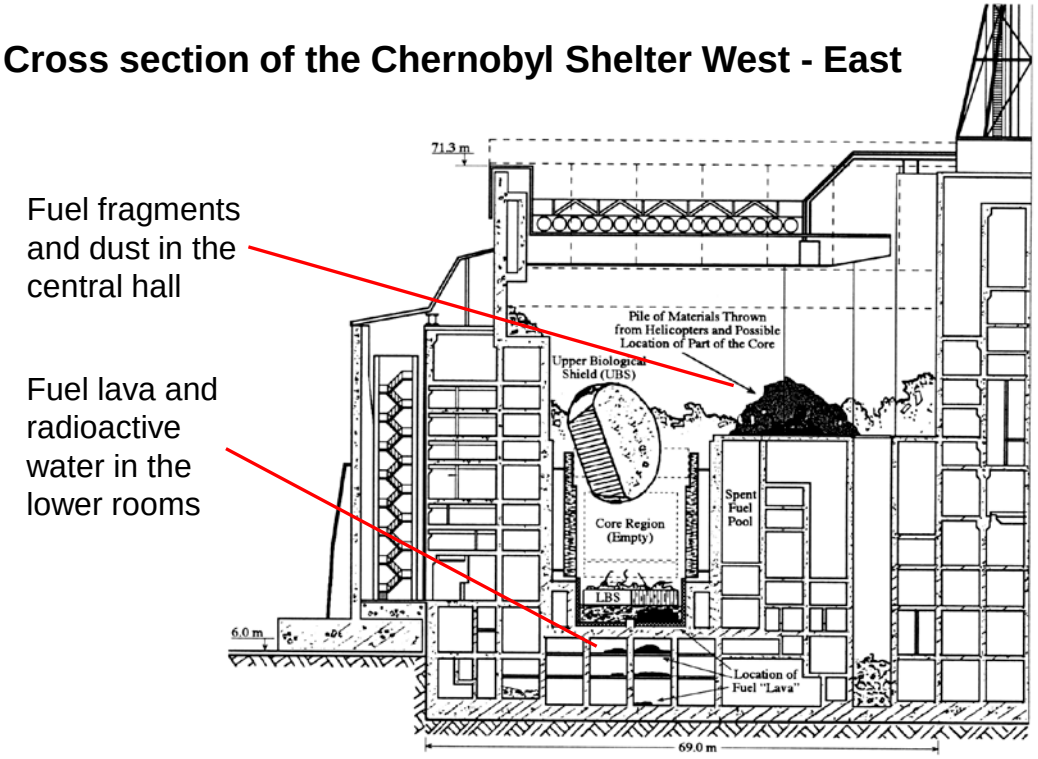
Spent Fuel Modification inside the Chernobyl Shelter

- Inside the Shelter remained
  - 96 % of the irradiated nuclear fuel inventory before the accident, (i.e. 180 t of Uranium of total radioactivity 7×10^{17} Bq) as
  - Radioactive dust ~ 25 t
  - Fuel element fragments ~120 t
  - Molten fuel lava of nearly 35 t
  - Several kg of Uranium and Plutonium solutes in water



Hot particles in the fuel dust

Cross section of the Chernobyl Shelter West - East

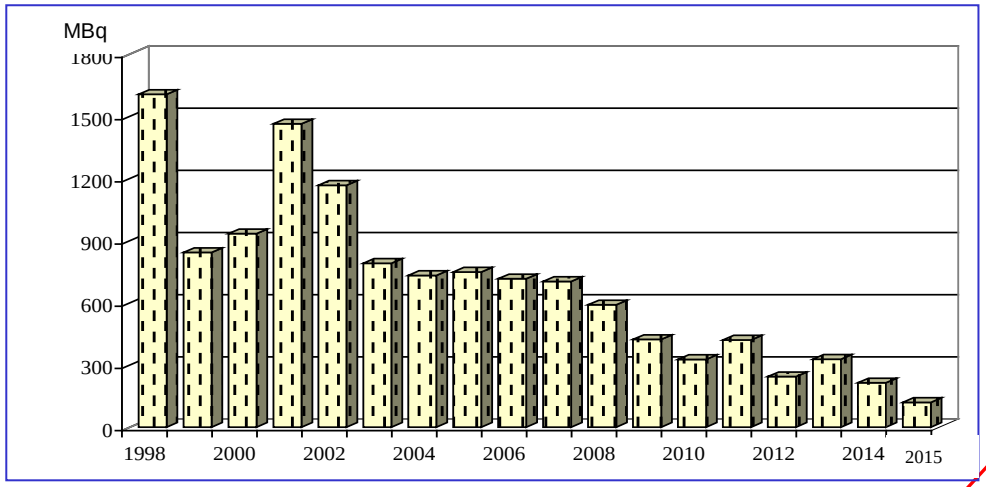


Fuel element fragments, graphite and fuel lava

Spent Fuel Dust and Ground Contamination

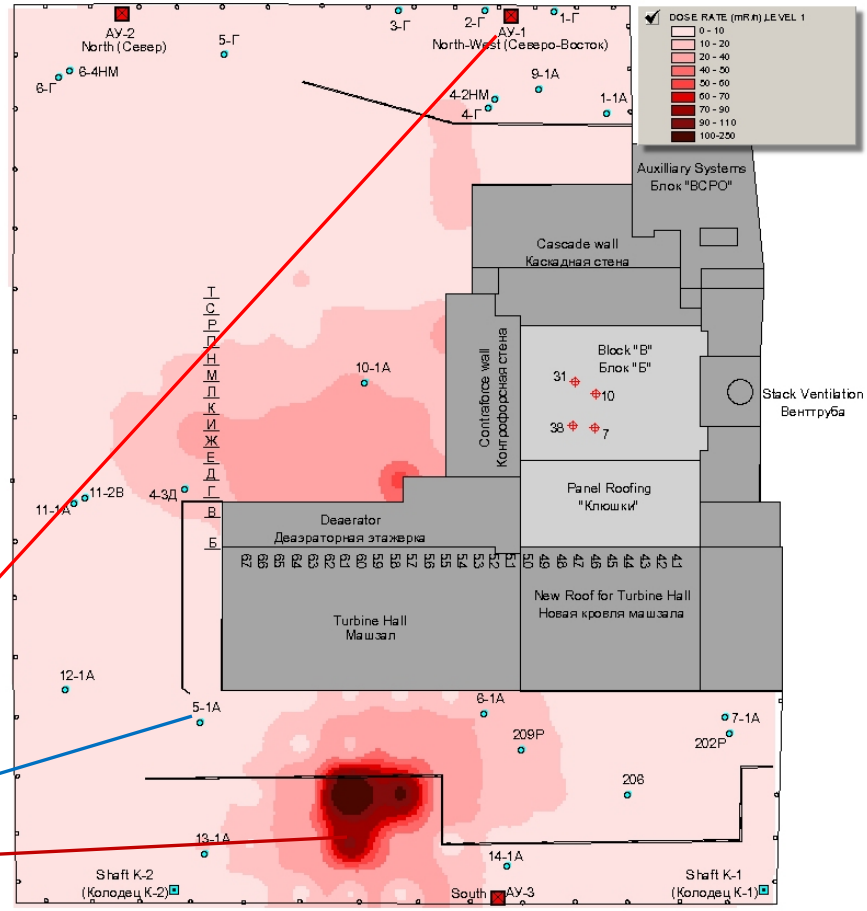
Degradation of the molten fuel during the last thirty years:

- residual heat decrease, temperature changes and influence of humidity
- from a glass kind into a brittle and porous matter
- water ingress, fuel leaching and transport into the lower rooms
- radioactive water from the unit 4 into unit 3, about 200 m^3 in 2015
- In central hall and upper rooms dry radioactive particles are generated
- dust becomes airborne and gets released through different roof openings and the ventilation stack
- contribute to inhalation and ground shine dose outside



Average yearly releases of radioactive aerosols through roofing leaks

Radiological Situation at the Shelter Site



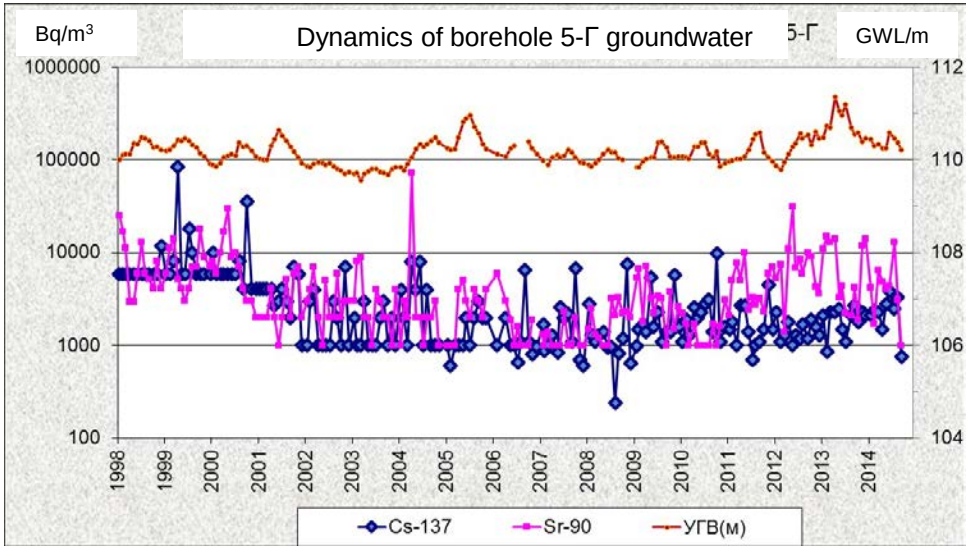
Dose rate 1 m above ground (mR/h) in 2012

- Aspiration units AY1 to 3 for aerosol sampling (red)
- Bore holes for ground water inspection (blue)
- Red spots indicate fuel burial

Groundwater Contamination at the Chernobyl Shelter Site

The annual groundwater Contamination

- concentrations of Sr-90 and Cs-137, e.g. for well 5-Г
- decreasing over the last years at the flow exit of the Shelter site towards the cooling pond
- permissible levels of drinking water in Ukraine are 96 Bq/l for Cs-137 and 45 Bq/l for Sr-90



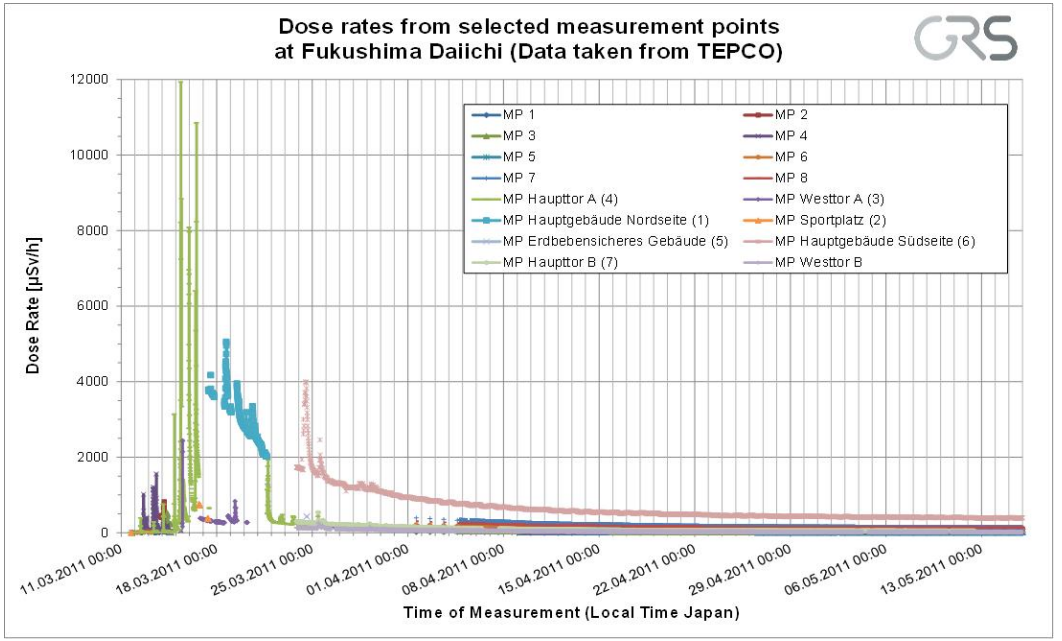
Concentrations Cs-137, Sr-90 (Bq/m^3) and Groundwater Level (GWL/УГВ) in borehole 5Г

The almost completed New Safe Confinement

- a huge construction, 250 m base line and 100 m height
- shifting over the Object Shelter planned for end of 2016
- cooling pond level is decreasing, shows already “islands”
- lowering of the water level influences the groundwater
- contaminated sediments at the banks will fell dry causing radioactive dust resuspension

Radioactive Releases after the Fukushima Accident

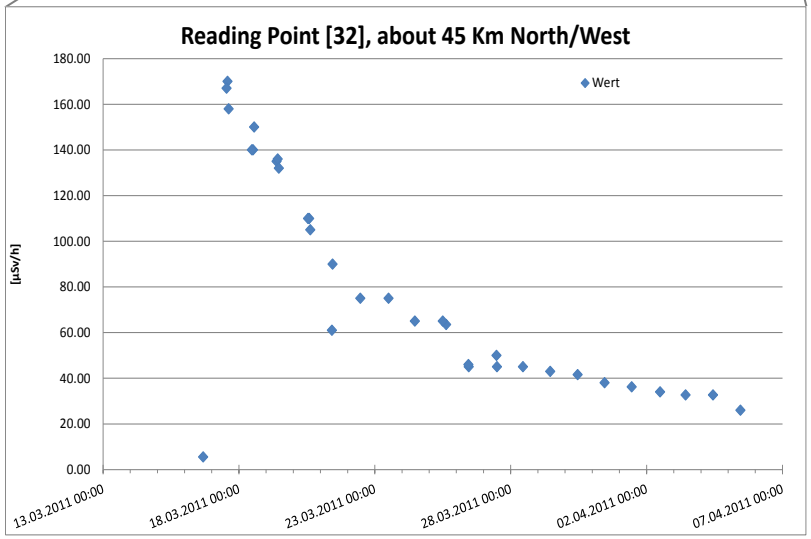
Source	Estimated total release (PBq)		
	Xe-133	I-131	Cs-137
ZAMG 2011		400	33
IRSN 2011	2000	90	10
1st report to IAEA	11000	160	15
1st report to IAEA		150	12
2nd report to IAEA		130	11
Terada et al.		124	9
TEPCO 2012	< 500	500	10
IRSN 2012	5950	197	21
Stohl et al.	15300		36,6
Winiarek et. al.		190-380	12
IAEA 2015	500 -15000	100-400	7-20
UNSCEAR 2008 (Chernobyl)	6500	1760	85

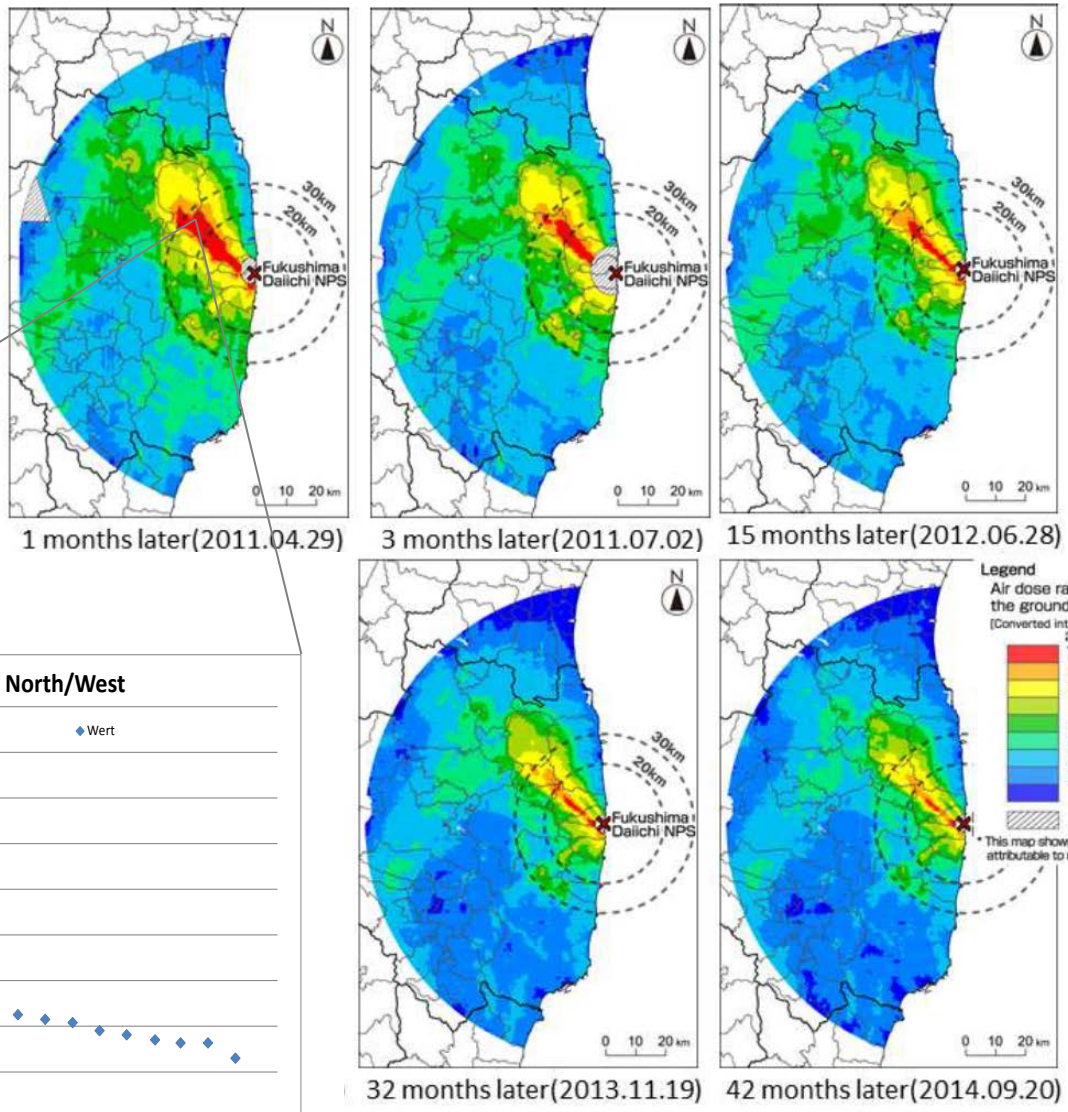


- Majority of releases from reactor units 1 to 3
- Soil samples showed mainly I-131, Cs-134 and Cs-137 depositions in the environment
- Mainly airborne releases; water-borne releases approx. 10 % for I-131 and 50 % for Cs-137 less
- Release estimations mainly based on dispersion calculation and simulations
- Total amount of airborne release estimated to be approx. one order of magnitude smaller compared to Chernobyl

Radiological situation in the vicinity of the Fukushima site

- Aerogamma campaigns starting on March 17, 2011
- Contamination mainly due to releases on March 15, 2011
- Local dose rate up to 180 µSv/h at 30 km distance
- Dose rate within 80 km zone decreased on average by 40 % between Nov 2011 and Nov 2012



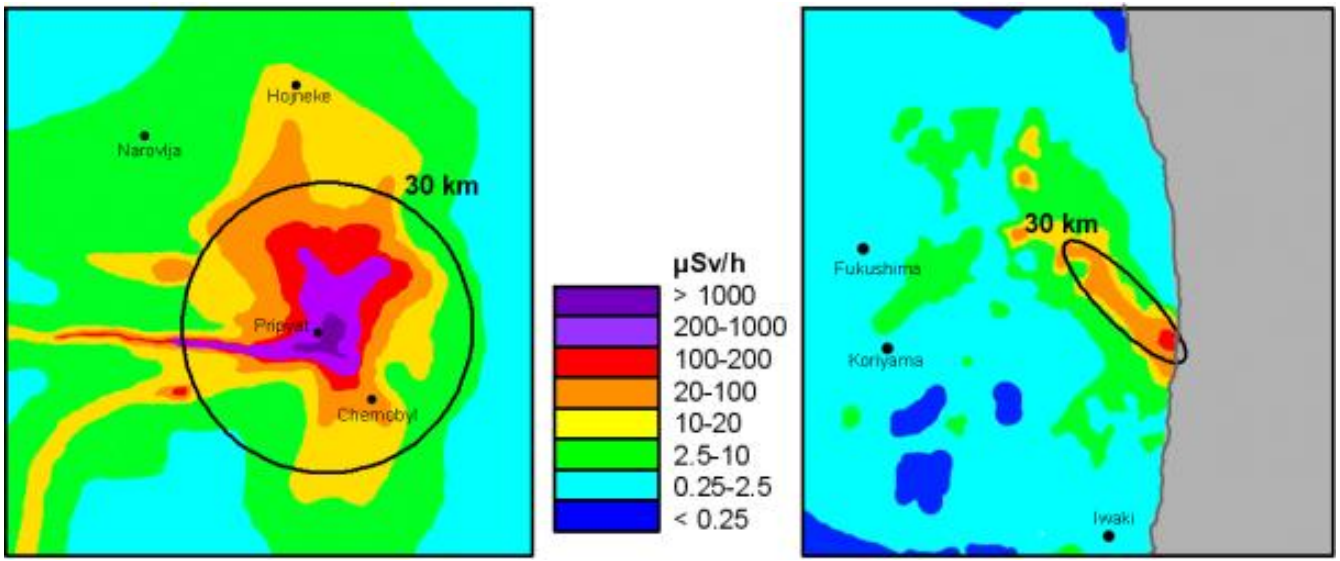


Air dose rate 1 m above ground for different reference dates at Fukushima area

Main differences between Fukushima and Chernobyl

- Course of accident
  - Uncontrolled increase in reactor output led to an explosion of reactor and subsequent multiple-day fire at Chernobyl
  - Hydrogen explosions and ventings at Fukushima

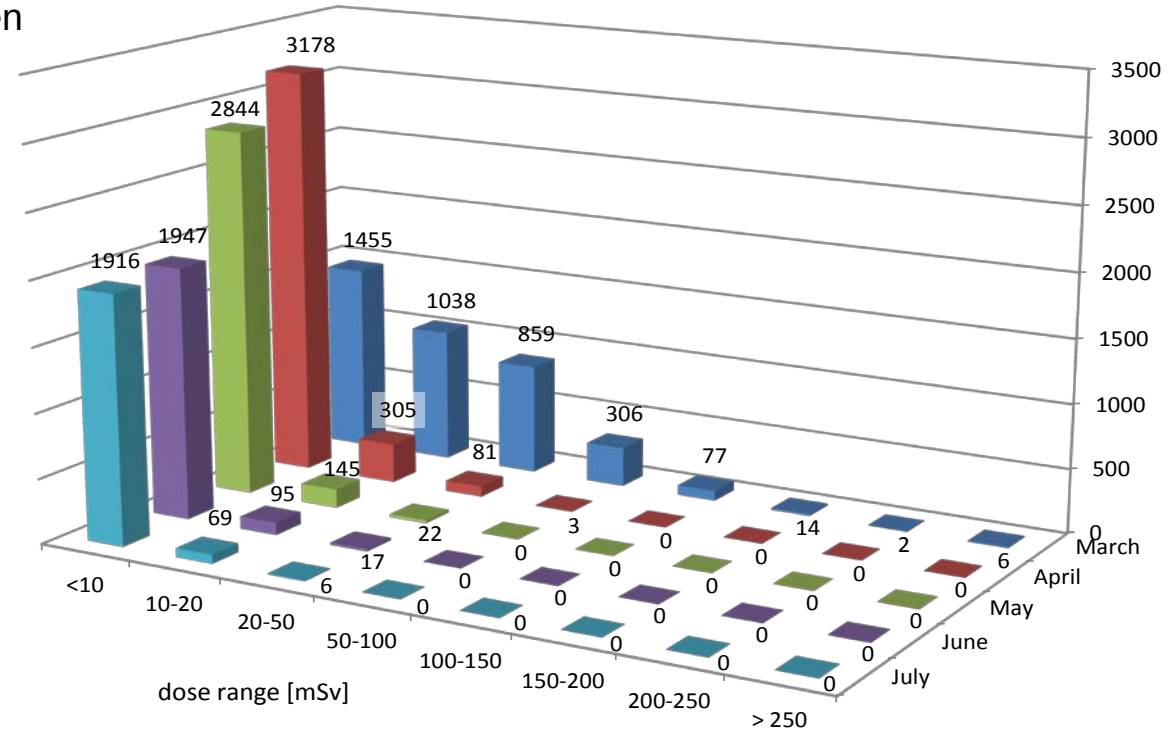
- Radioactive releases
  - Total amount one magnitude smaller at Fukushima
  - Larger amounts of hardly volatile radioactive substances such as plutonium and strontium released in Chernobyl
  - Transportation to higher altitudes due to the fire in Chernobyl
  - Different to Chernobyl, most of releases at Fukushima were blown from the west to the Pacific Ocean



Comparison of the air dose rate 1 m above ground in the vicinity of Chernobyl and Fukushima, referring to about one month after the accidents

Main differences between Fukushima and Chernobyl

- Exposure of Workers
  - In control of fire and the work to cover open reactor core, exposures of personnel in Chernobyl higher (300 persons taken to hospital; 134 persons with symptoms of acute radiation disease; 28 persons died of radiation illness, further 11 persons)
  - At Fukushima 6 persons with effective doses above 250 mSv (max. 680 mSv) due to inhalation of radioactive substances in Unit 1 control room on March 12, 2011 after hydrogen explosion
  - Three workers got in contact with highly contaminated water in Block 3 on March 24, 2011 and received effective doses above 170 mSv (< 250 mSv) with skin doses up to 2-3 Sv at Fukushima
  - According to WHO in 2013, seven people died at Fukushima in the course of the accident with no correlation to radiation exposure



Exposure of workers at Fukushima in the first month after accident

Conclusions

- Different courses of the accidents at Chernobyl and Fukushima
  - the fire at Chernobyl lifted radioactive aerosols into big heights
  - source term of the released radioactivity about ten times higher at Chernobyl
  - at Chernobyl hardly volatile radioactive substances, e.g. Plutonium and Strontium released
  - Release period at Chernobyl about ten days, at Fukushima essentially longer
- Contamination of land and water
  - from Chernobyl dispersion of radioactivity all over Europe
  - from Fukushima limited area under the plume northwest of the NPP
  - from Fukushima contamination of big volumes of sea water and ground water
- Countermeasures
  - qualitatively comparable for both sites, e.g.
  - evacuation, resettlement, restriction of residence,
  - decontamination of land and living areas
  - limitation of food production and consumption
- Long term remediation
  - decontamination of land and water reservoirs
  - removal of fuel containing materials and management of radioactive waste