Pathway of Radioisotopes from Land Surface to Sewage Sludge

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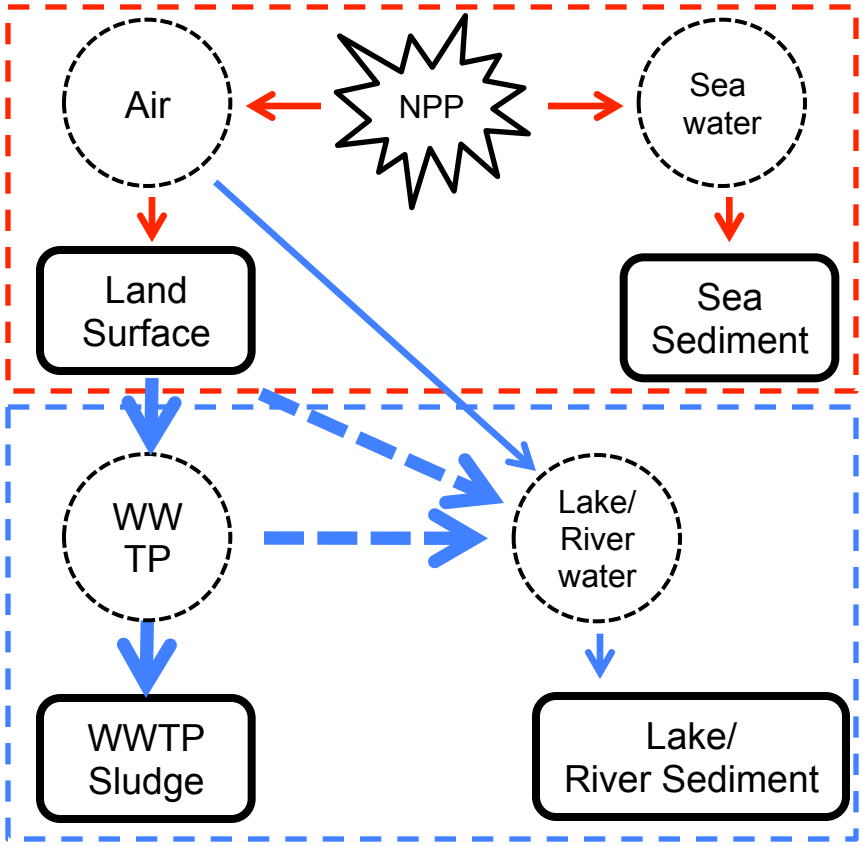
Several well-known pathways for radioisotopes (marked in red)

most important for human exposure: **air** (short term) and **soil** (long term)

Redistribution by terrestrial processes (marked in blue)

additional sinks: **sludges** and (terrestrial) **sediments** (sources of radiation and for redistribution)

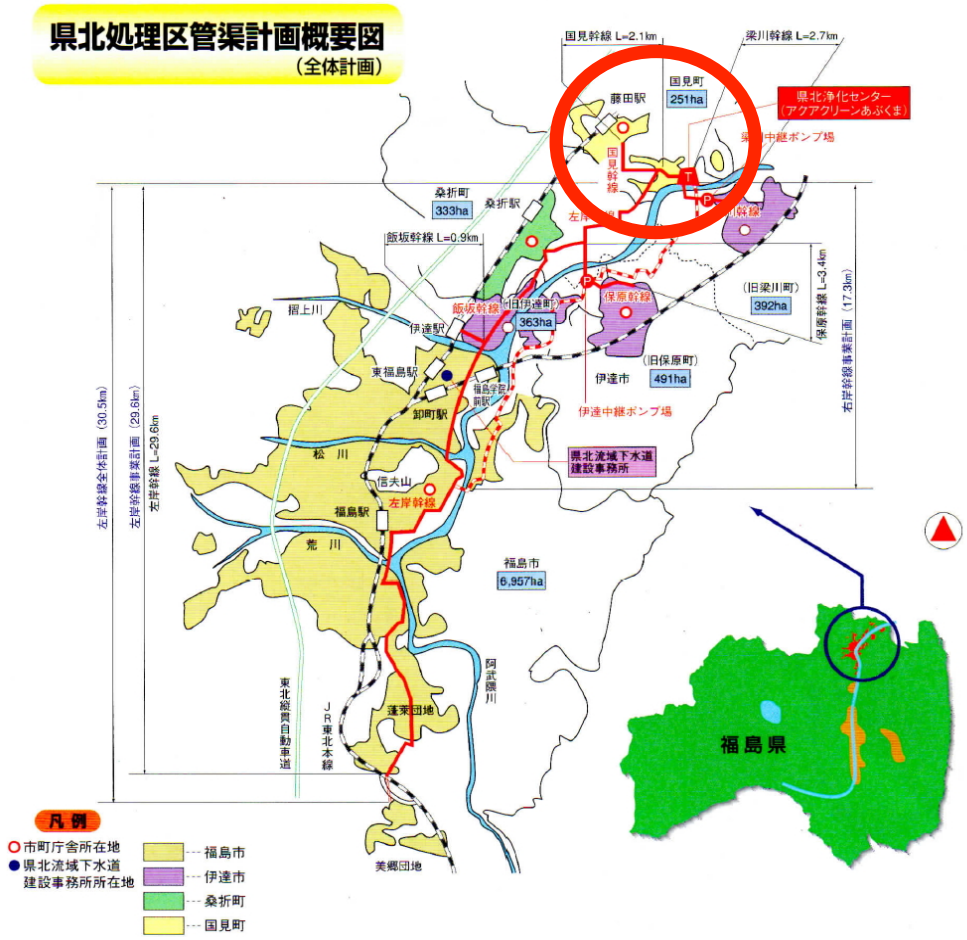
Hypothesis: **erosion** is one dominating process



Environmental pathways for emitted radioisotopes

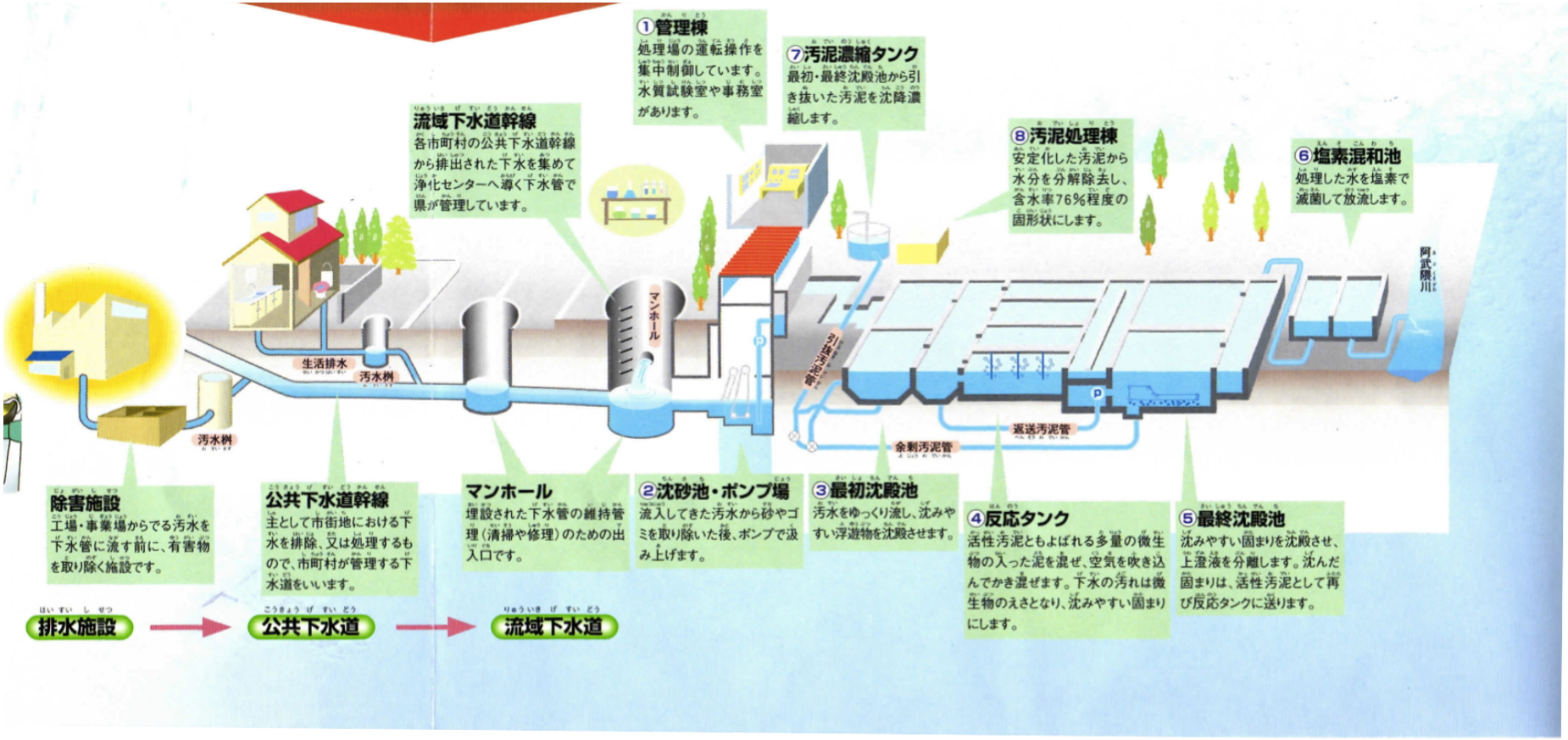
Data set: time series of sewage sludge from Fukushima city sewage plant

Location:	downstream of city
Capacity:	70000 m^3/d
Drained area:	41 km^2
Population served:	185000
Sewer system:	separated (waste and rain water)
Effluents:	Abakuma river



Reginal map (from Fukushima city WWTP information leaflet)

Data set: time series of sewage sludge from Fukushima city sewage plant



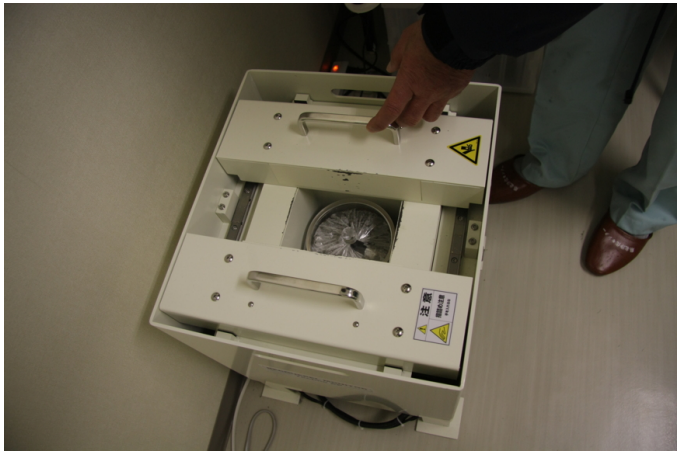
Sewer system scheme (from Fukushima city WWTP information leaflet)

Data set: time series of sewage sludge from Fukushima city sewage plant

Sludge is dried and stored on site when above limit

Semi-automatic measurement by gamma spectrometer (installed after accident)

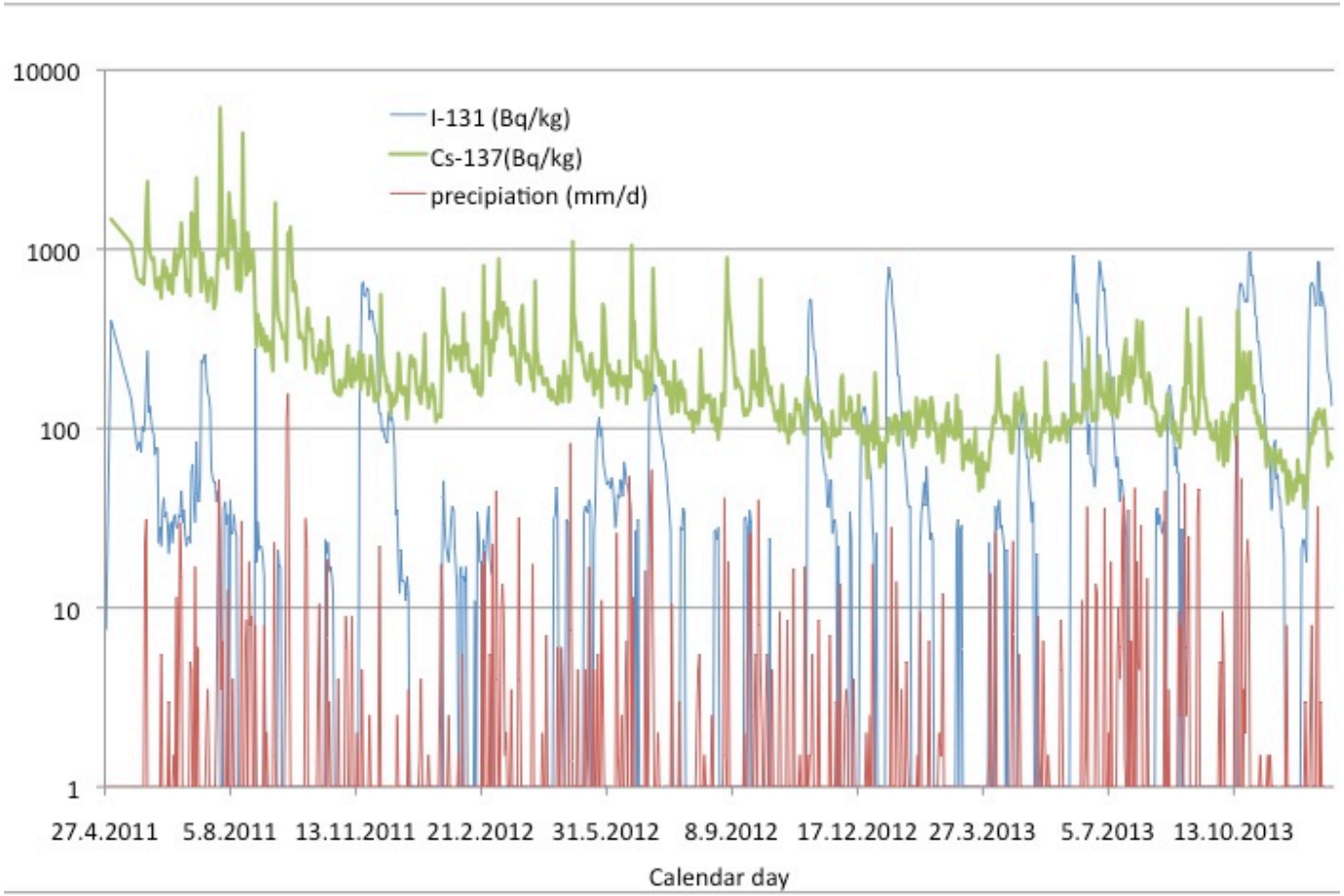
Radiation levels are very low



Sludge storage and measurement device (photos: D. Pittauerová)

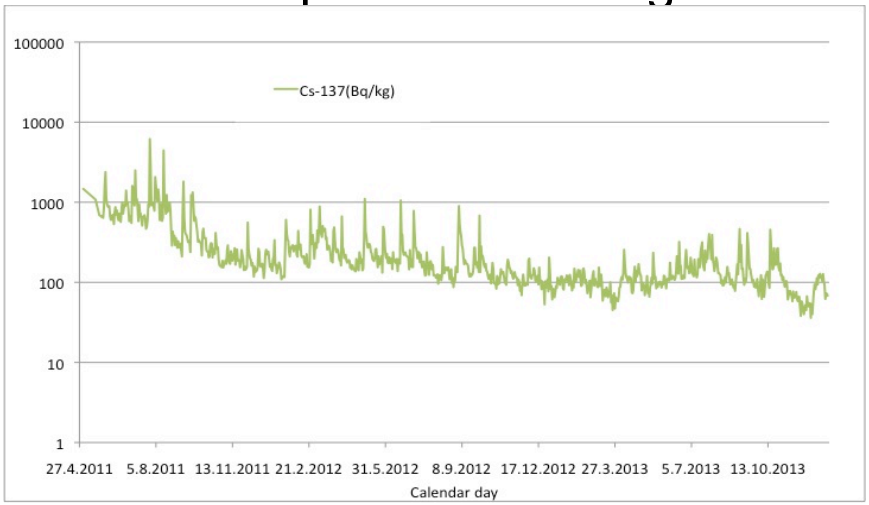
Data set: time series of sewage sludge from Fukushima city sewage plant

- ^{137}Cs data decrease monotonically, with spikes and seasonal trend
- ^{137}Cs data are relatively low, in view of the ground contamination level
- Late ^{131}I data appear not to be event-related (see below)

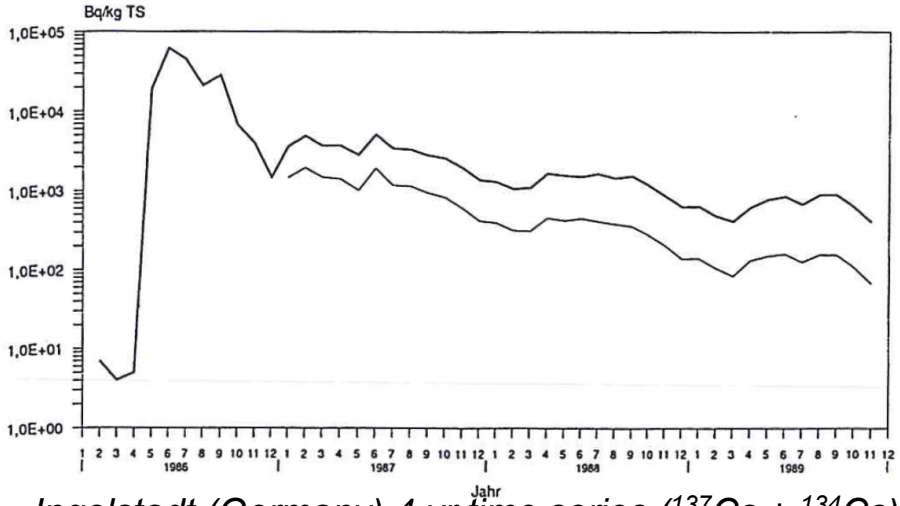


Fukushima plant time series (complete data set)

Comparison of sludge ^{137}Cs time series with Chernobyl data



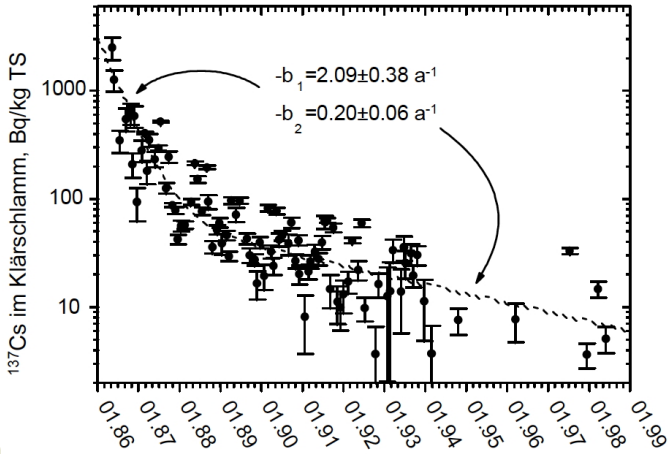
Fukushima plant 2.6 yr time series (^{137}Cs)
Deposition ca. ***300 kBq/m²*** *(this work)*



Ingolstadt (Germany) 4 yr time series (^{137}Cs + ^{134}Cs)
Deposition ca. ***50 kBq/m²***
(Gans et al., Korrespondenz Abwasser 1991, reproduced with permission)

- data sets show similar patterns
- ^{137}Cs concentrations derease **with ca. 1 yr half-life** initially, later on more slowly
- European values are (relatively) higher than Japanese, although deposition was lower

right:
Vienna 14 yr time series (^{137}Cs)
Deposition ca. ***20 kBq/m²***
(Strebl et al., Unweltbundesamt, Wien 1998)



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A closer look at Fukushima city sewage plant data: ^{137}Cs

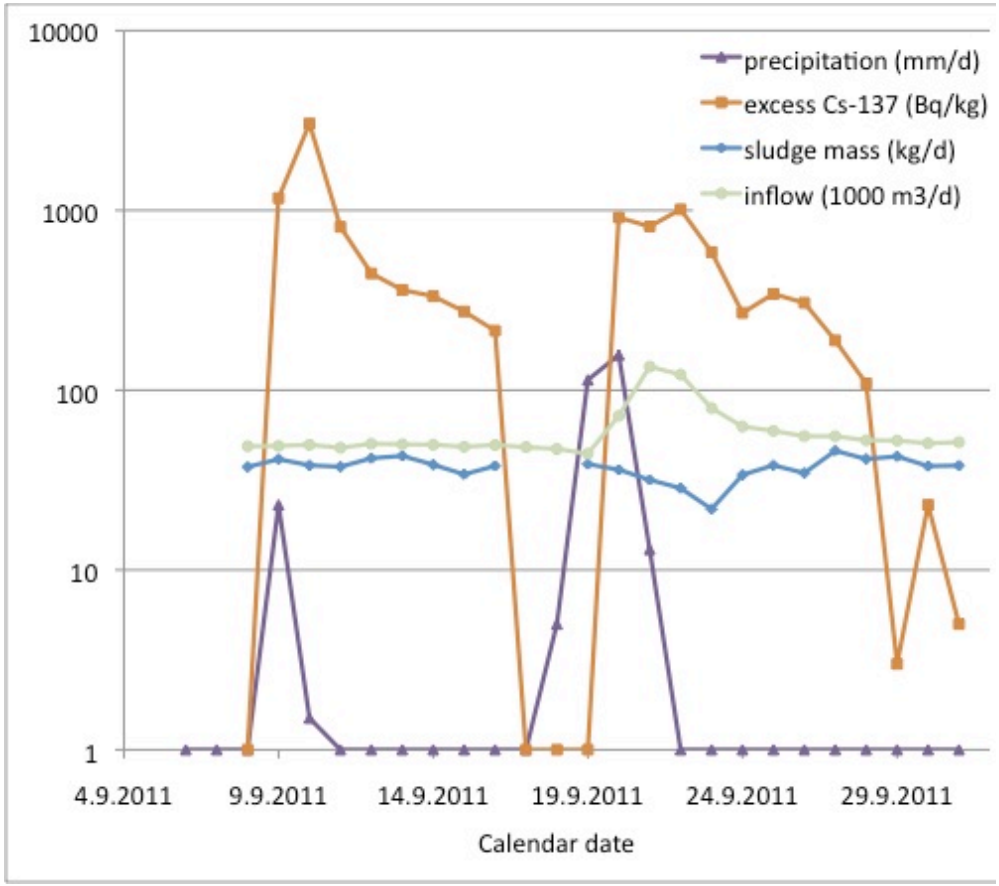
Peaks in ^{137}Cs data are always correlated with rain events

Regular rain event (Sept. 9 to 11)

- „excess“ (above baseline) ^{137}Cs increases sharply, declines more slowly (ca. 2 d half-life)
- Inflow is not affected
- Sludge production is constant

Extreme rain event (Sept. 17 to 21)

- Similar ^{137}Cs pattern
- Inflow is dramatically increased
- Sludge mass is decreased

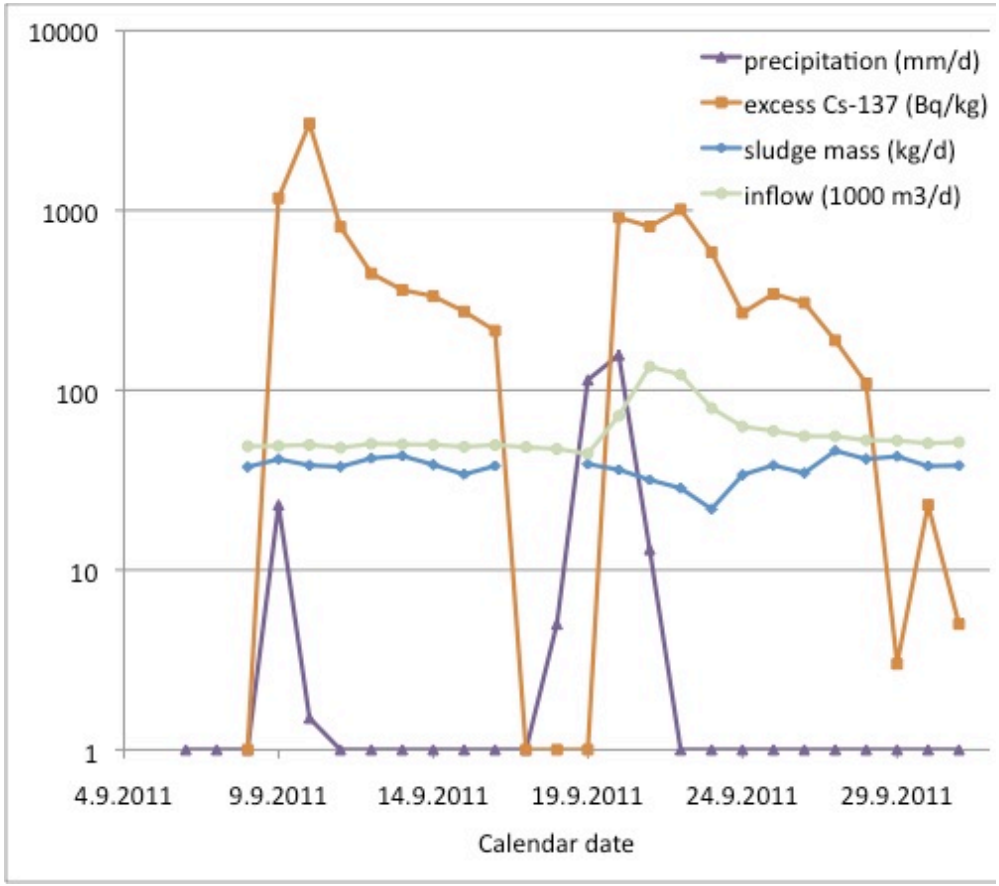


Fukushima city plant data Sept. 2011 with two rain events

A closer look at Fukushima city sewage plant data: ^{137}Cs

- In normal operation, only small erosional input (leakage from rainwater system)
- Explanation for low ^{137}Cs concentration in sludge
- Most ^{137}Cs is directed to surface waters directly
- Extreme event data are not typical
- Sludge data may be useful as indicator for erosion, and for modeling of sewage plant processes

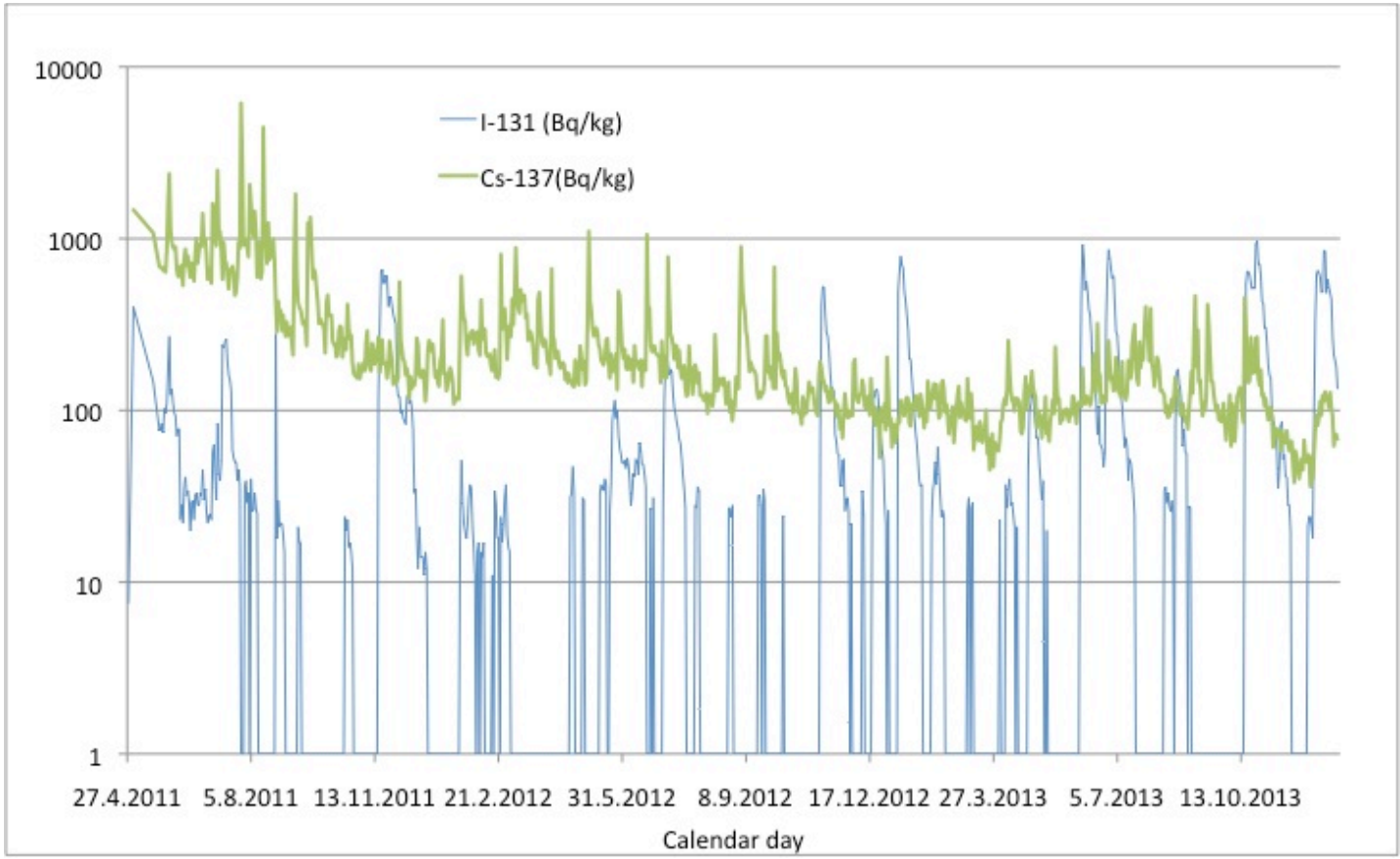
(quantitative evaluation in progress)



Fukushima city plant data Sept. 2011 with two rain events

A closer look at Fukushima city sewage plant data: ^{131}I

- Late ^{131}I data appear not to be event-related
- Thyroid therapy unsing ^{131}I is a common medical procedure
- Patients leave the hospital with residual activity, often above 100 MB!
- ^{131}I reaches the environment via the sewer system
- ^{131}I can be used as tracer



Fukushima plant time series (^{137}Cs and ^{131}I)

Conclusions, outlook

- Time series of ^{137}Cs in sewage sludge show a characteristic behaviour
- Time evolution of recent (Fukushima NPP) and historic (Chernobyl NPP) data are comparable
- Rainfall-driven erosion is the dominating effect
- Sewage sludge data may be useful for quantitative erosion studies

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