Freshwater countermeasures

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Freshwater dose pathways

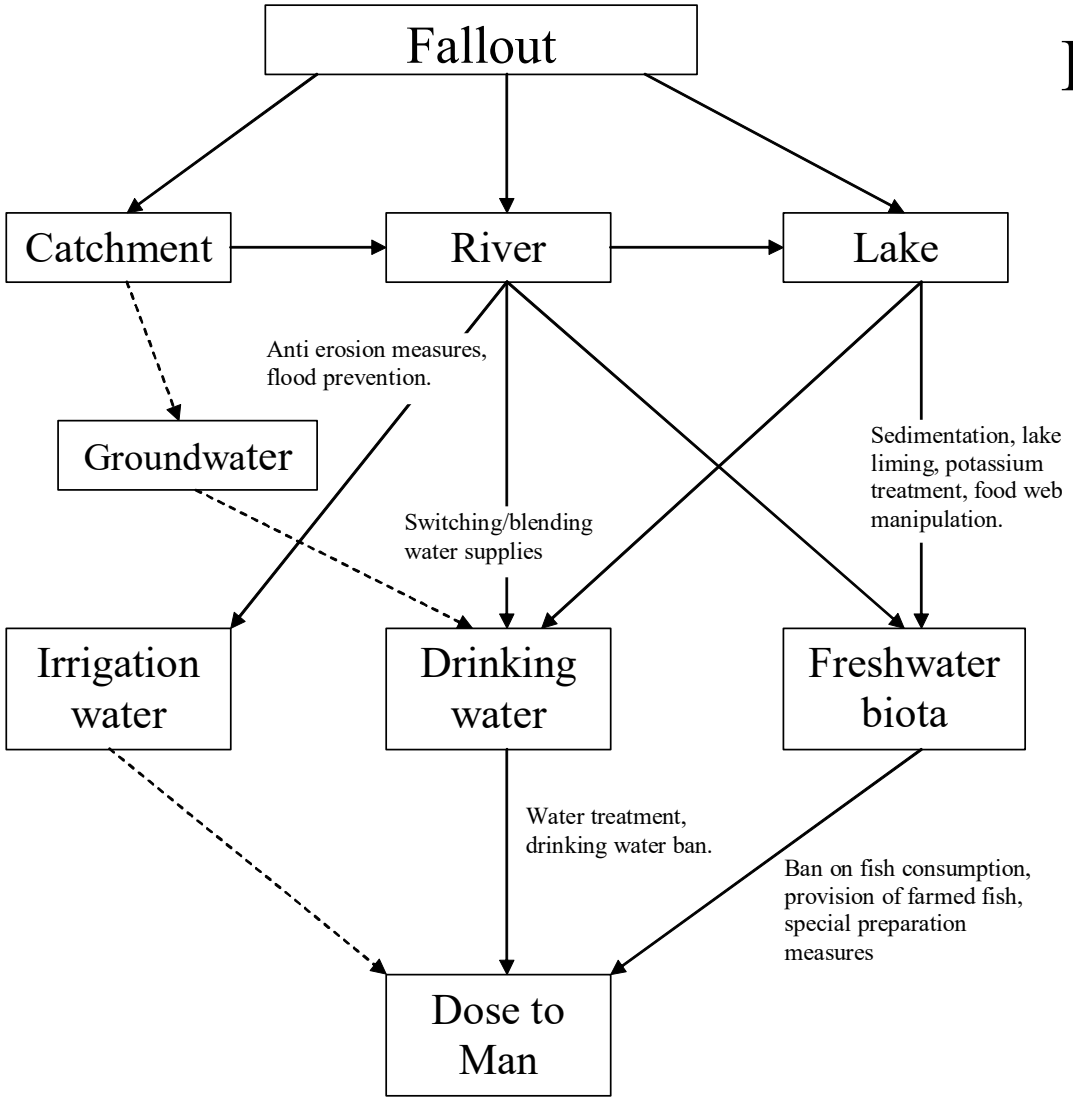


Figure 1. Freshwater dose pathway indicating potential intervention measures. Dashed lines indicate pathways of lower potential importance.

Smith, J.T., Voitsekhovitch, O. et al. A critical review of aquatic countermeasures *J. Env Rad.* **56, 11-32.**

Fear of contamination of the Pripyat-Dnieper reservoir system

Freshwater internal doses - minor compared to terrestrial

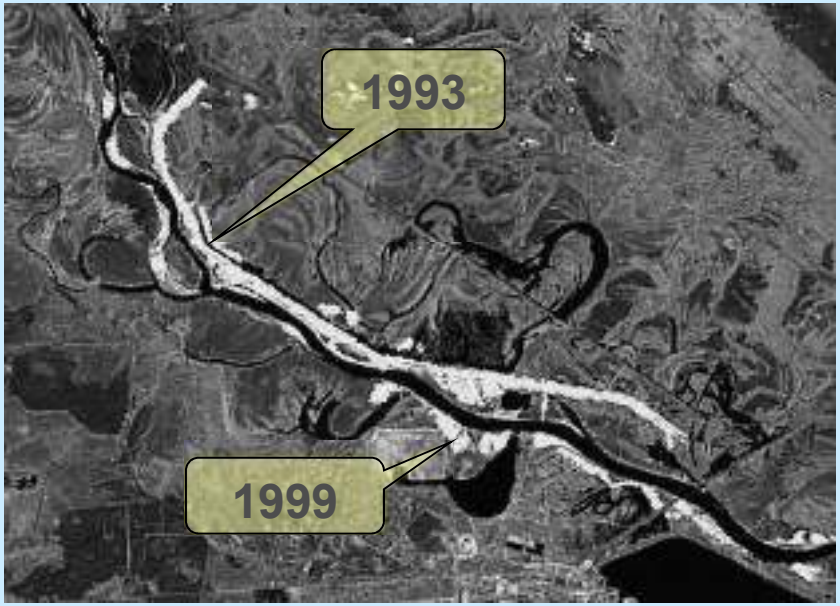
- Drinking water: dose very minor except in the first few weeks;
- Freshwater fish/foodstuffs – activity concentrations can be very high, but doses generally low (low consumption rates) except to critical groups (e.g. fishermen and their families);

Drinking water pathway – short term

- Switching/blending supplies is effective, but requires rapid response and an integrated network.
  - Groundwaters typically clean.

- Radioactivity removed at water treatment:
  - Removed with sediments and filtration e.g. by activated charcoal
  - Problems of high activity concentrations in removed sediments/filter systems.

General View



Flood protective dam has been constructed

Drinking water pathway – long term

- Sediment trapping dams were ineffective;
- Temporary increases in Sr-90 (from ~ 1Bq/l to 10 Bq/l during spring flooding of the Pripyat.
- Dam around the Pripyat floodplain was effective, but only implemented some years after the accident and only reduced relatively small peaks in ^{90}Sr concentration during flooding – effectiveness in dose reduction (or not) is controversial.

Drinking water pathway

- Levels of ^{137}Cs and ^{90}Sr in Kiev Reservoir water fell within one year to around 1 Bq/l or less.
- This compares with
  - up to 6 Bq/l in some mineral waters;
  - 10-13 Bq/l in sea water.
  - Natural potassium-40 in some foodstuffs of 100-200 Bq/kg

Drinking water pathway

- Public concern over drinking water supply was much greater than the real risk, both after Chernobyl and Fukushima.

Fish consumption pathway

Fish consumption pathway

- I-131 in fish from the Kiev Reservoir
  - 6000 Bq/kg (May 1986)
  - 50 Bq/kg (end June 1986)
- Cs-137 in fish:
  - Devoke Water, UK ~ 1000 Bq/kg in 1987
  - Lake Vorsee, Germany < 5000 Bq/kg, 1987
  - Lake Svyatoe, Belarus up to 100,000 Bq/kg, 1997
  - Lakes and rivers around Fukushima (2014) – mostly below 100 Bq/kg, but up to hundreds (some rivers) or thousands in lakes/irrigation ponds.
- Sr-90 in fish
  - Much less significant than Cs-137

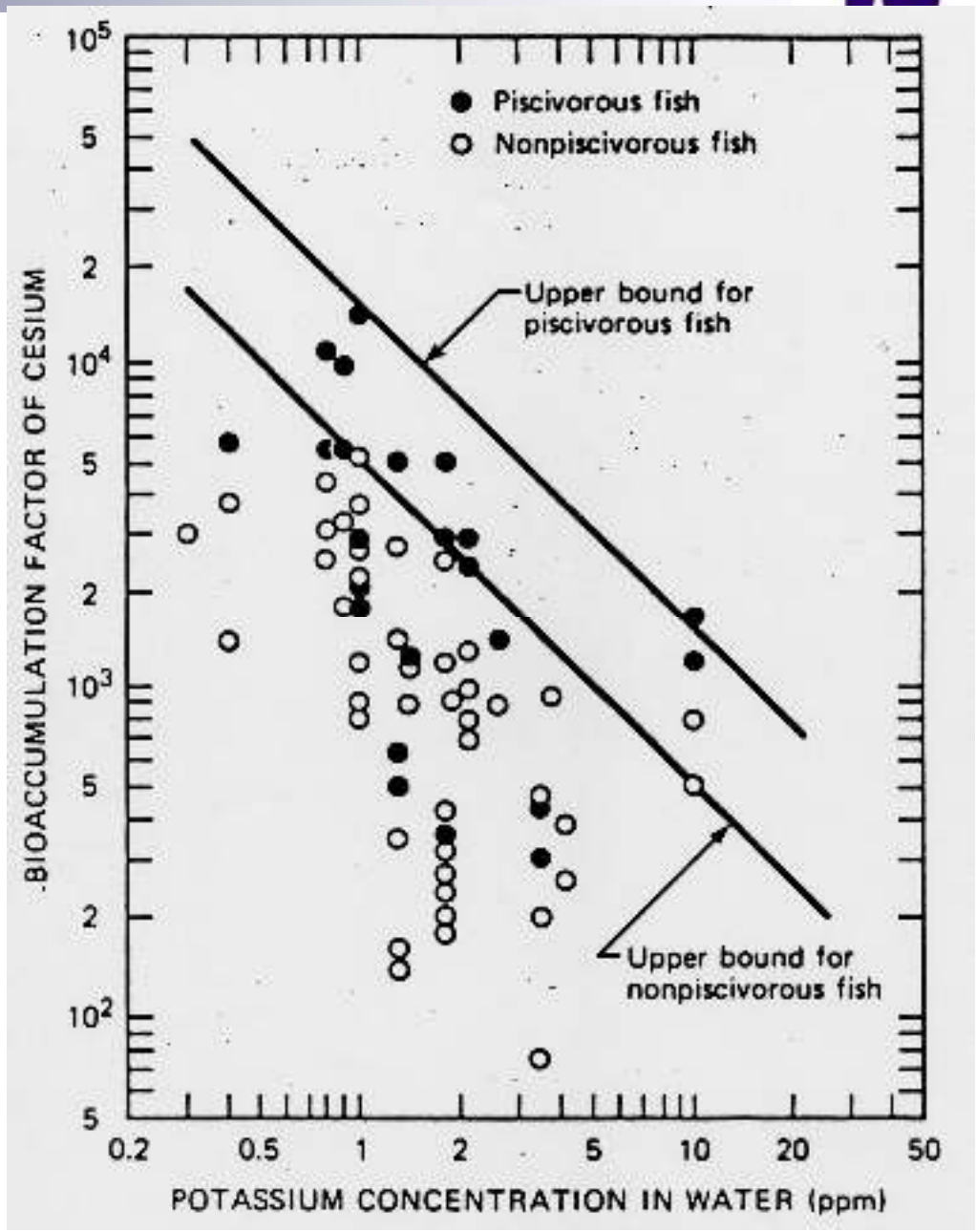
Fish consumption pathway

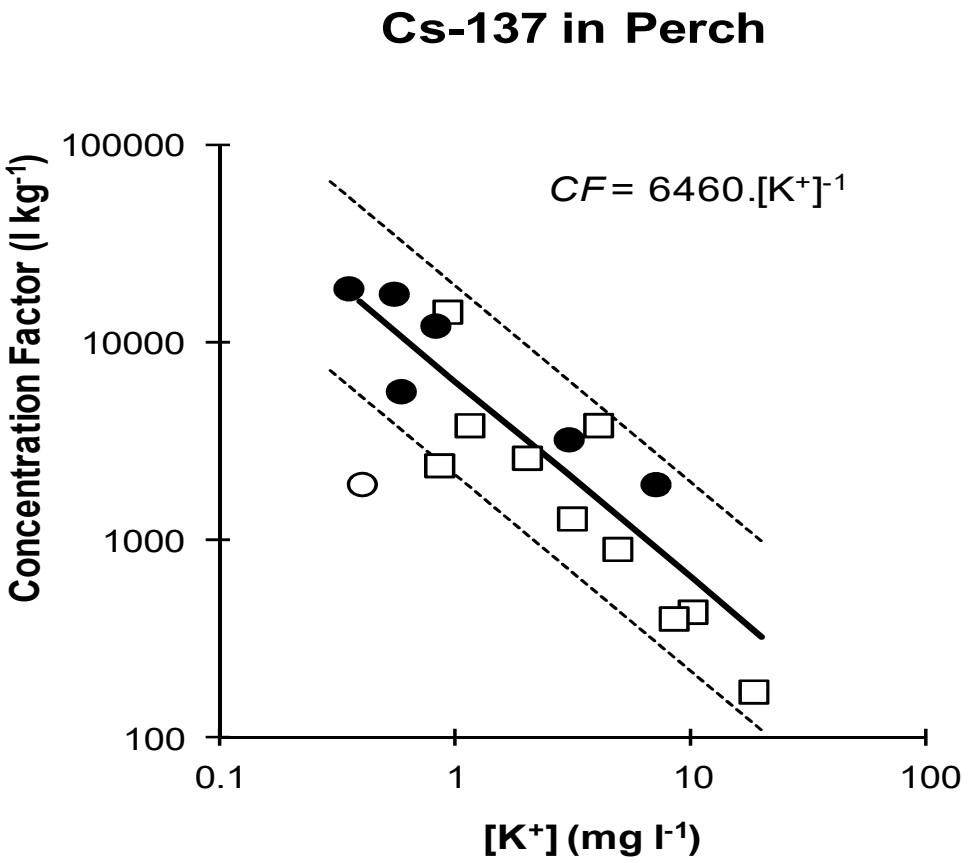
- Bans on sale/consumption of freshwater fish in parts of fSU, Scandinavia and Germany and in parts of Japan after Fukushima;
- Bans/recommendations often not adhered to in fSU.
- Guidelines on maximum recommended consumption rates may be appropriate;

Testing a countermeasure

Caesium-potassium model from measurements in lakes pre-Chernobyl

Vanderploeg et al. 1975

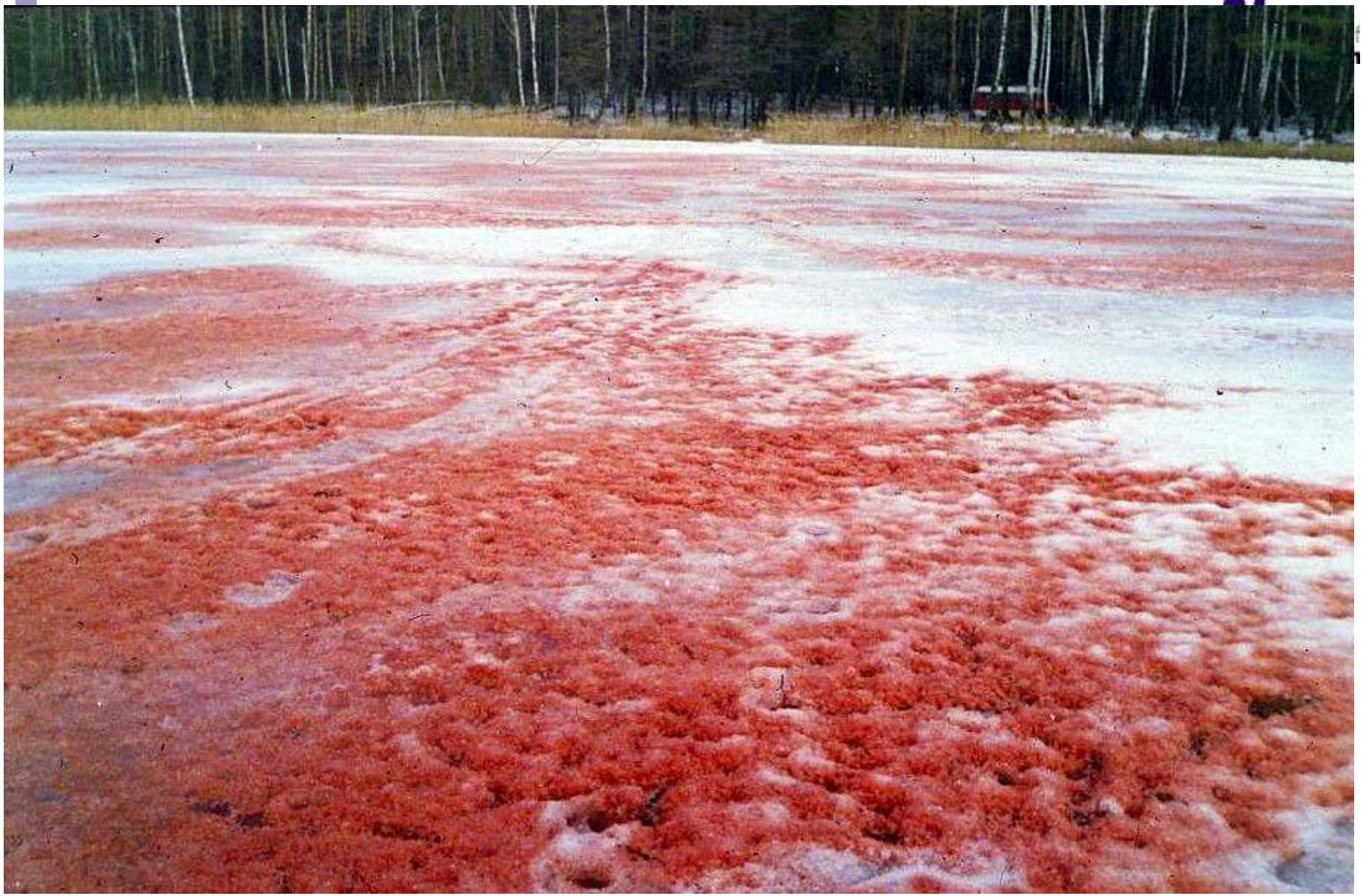




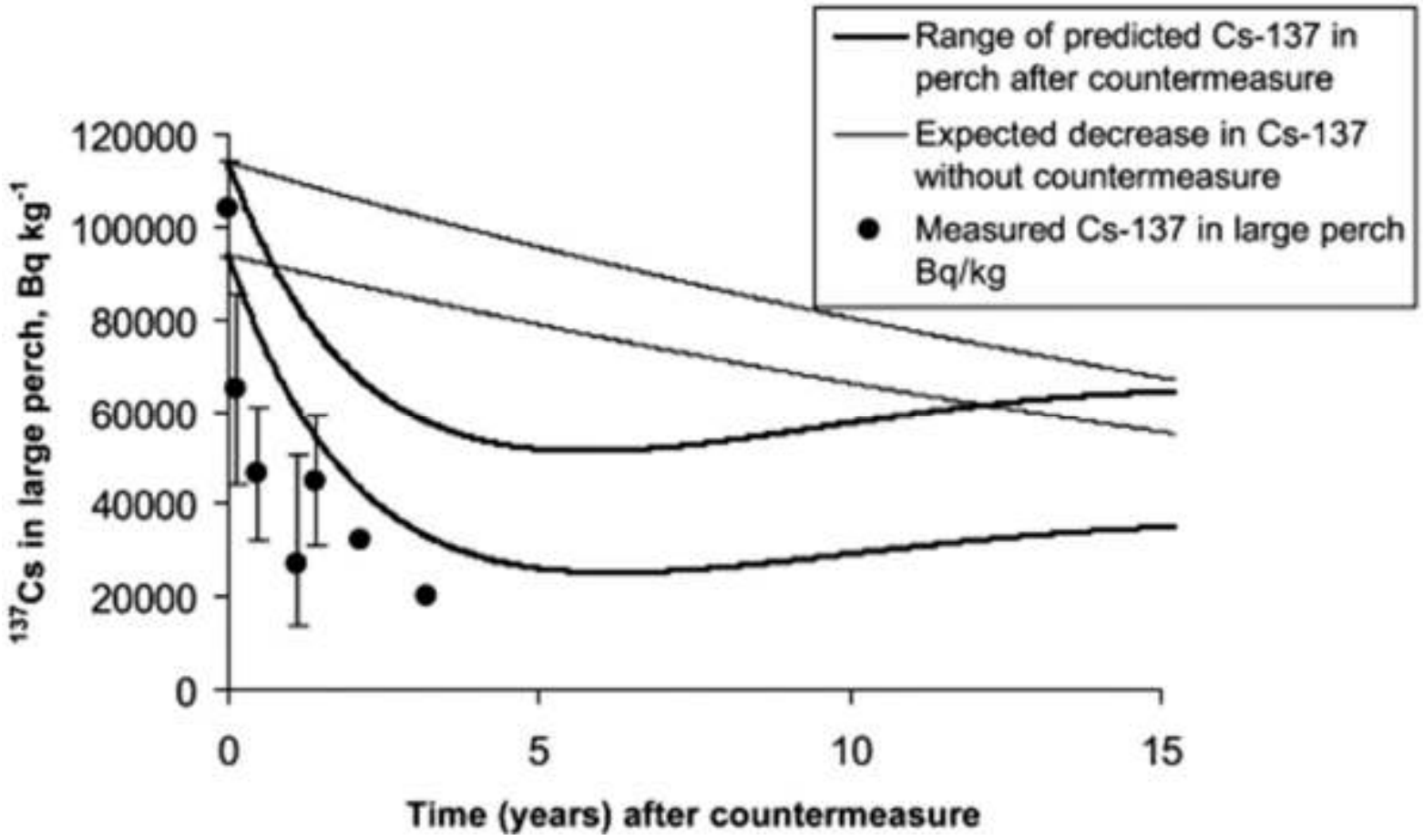
Cs-137 in fish goes down as potassium goes up

Can we use this to reduce Cs-137 in fish ?

“AQUACURE” project with Belarus Academy of Sciences

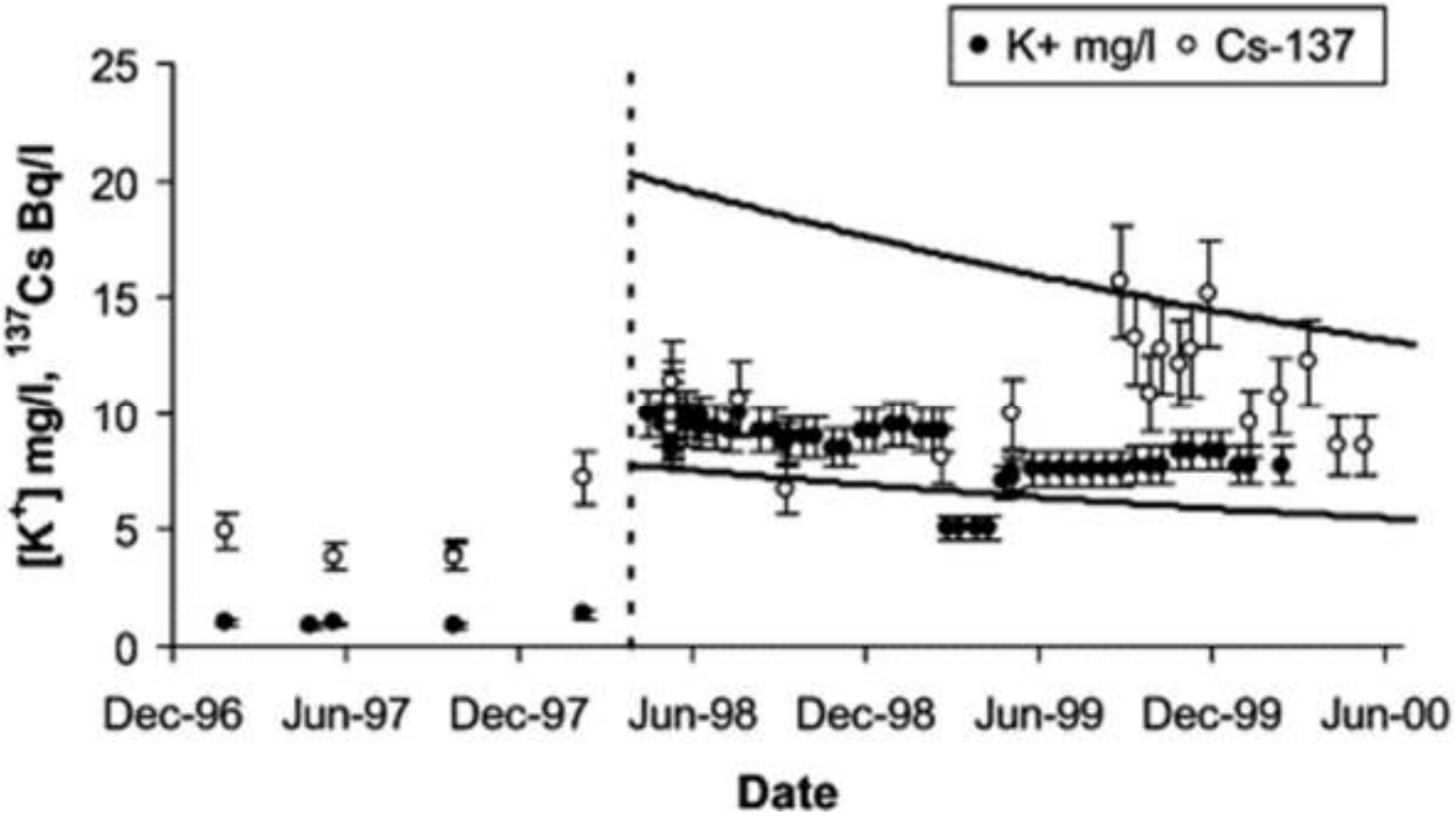


Result of 10 x increase in potassium in L. Svyatoe, Belarus



Smith, James T., et al. *Science of the Total Environment* 305.1 (2003): 217-227.

Changes in water chemistry



Countermeasure for Sr-90 ?

- A similar inverse relationship between ^{90}Sr in fish and calcium concentration in water has been observed.

- Ca additions could work in the case of ^{90}Sr contamination, but this has not been tested.

Fish consumption pathway

- Disadvantages of chemical additions:
  - Can be expensive;
  - Can influence the ecology of the water body;
  - Problems maintaining high K or Ca levels;
  - Countermeasure can increase radioactivity in the water.

Fish consumption pathway

- Food preparation measures can be effective:
  - For ^{90}Sr contamination, eat only muscle tissue (~90% of ^{90}Sr is in the bones and skin);
  - Salting fish may significantly reduce ^{137}Cs concentrations, but affects taste, nutritional value of the fish;
  - May not be publically acceptable

Fish consumption pathway

- Fish farms:
  - ^{137}Cs is absorbed by the fish mainly via ingestion: farmed fish (eating clean food) relatively uncontaminated.
  - ^{90}Sr may also be absorbed via the gills.
  - Chemical additions could work well for fish farms but may not be necessary.

Disadvantages of countermeasures

- Often very expensive – is the cost per Person-Sv justifiable ?
- Dose to clean-up workers; waste generation

- Potential unintended consequences to humans (e.g. salting fish can reduce Cs, but excessive salt intake may outweigh health benefit). Also potential ecosystem damage from large scale measures.

Sometimes doing nothing: "Monitored Natural Attenuation" can be the best option.