

Recent U.S. Experience with Pu/Am Incidents



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REAC/TS

- The Radiation Emergency Assistance Center/Training Site (REAC/TS) is a U.S. Department of Energy (DOE) facility in Oak Ridge, Tennessee.
- REAC/TS' mission is to provide medical management of radiation accident victims
- REAC/TS is a member of REMPAN
- REAC/TS staff includes physicians, nurses, and health physicists

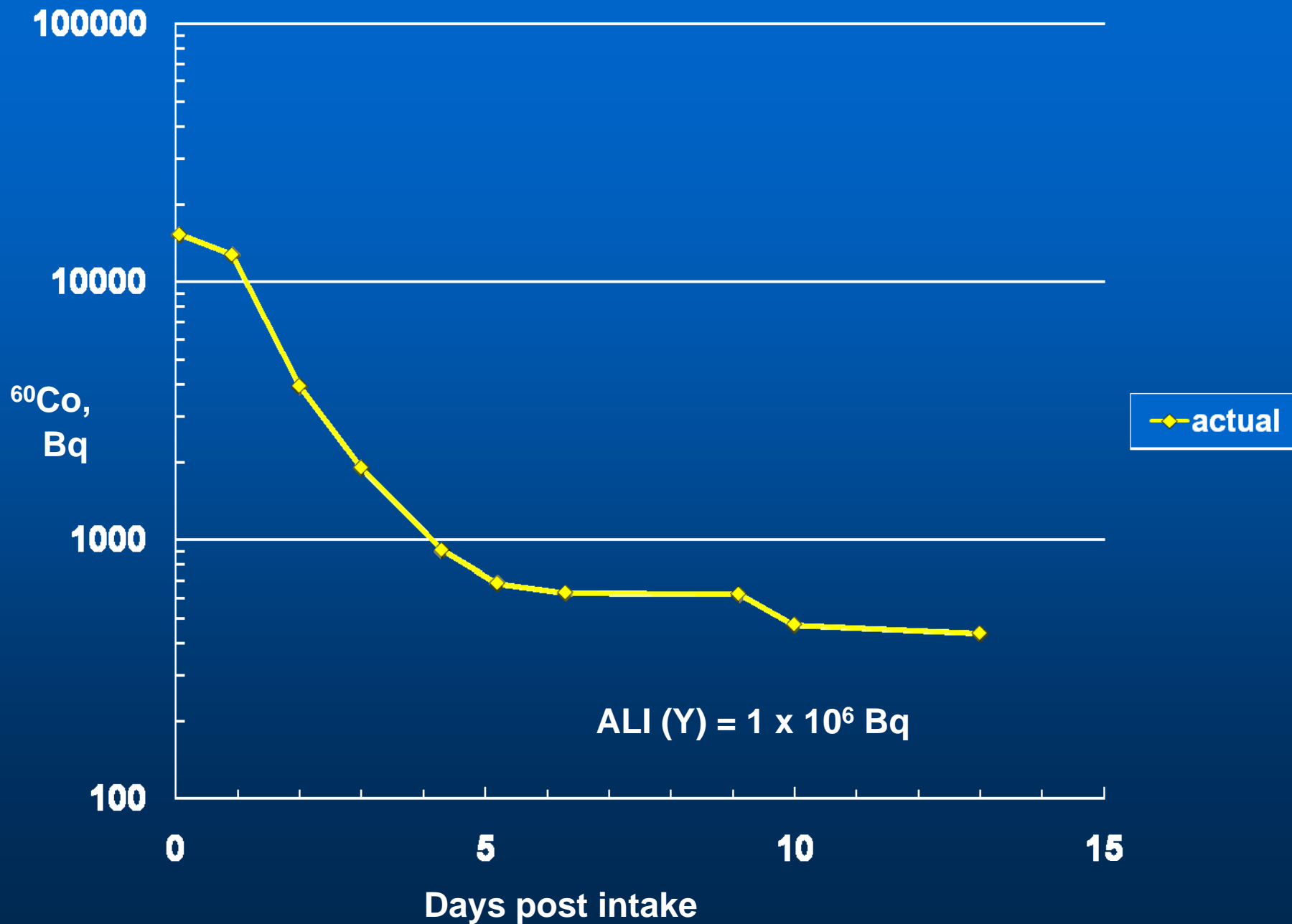
OBJECTIVES

- Discuss lessons learned from industrial accidents involving internalization of transuranic radionuclides
- Discuss considerations for initiating treatment of internal contamination and methods for assessing the efficacy of that treatment

Case # 1 Nuclear Power Plant

- Two workers removing debris from a fuel transfer canal during a refueling outage
- No respiratory protection or air sampling provided
- Workers found to have facial contamination on exit, and referred for whole-body counts

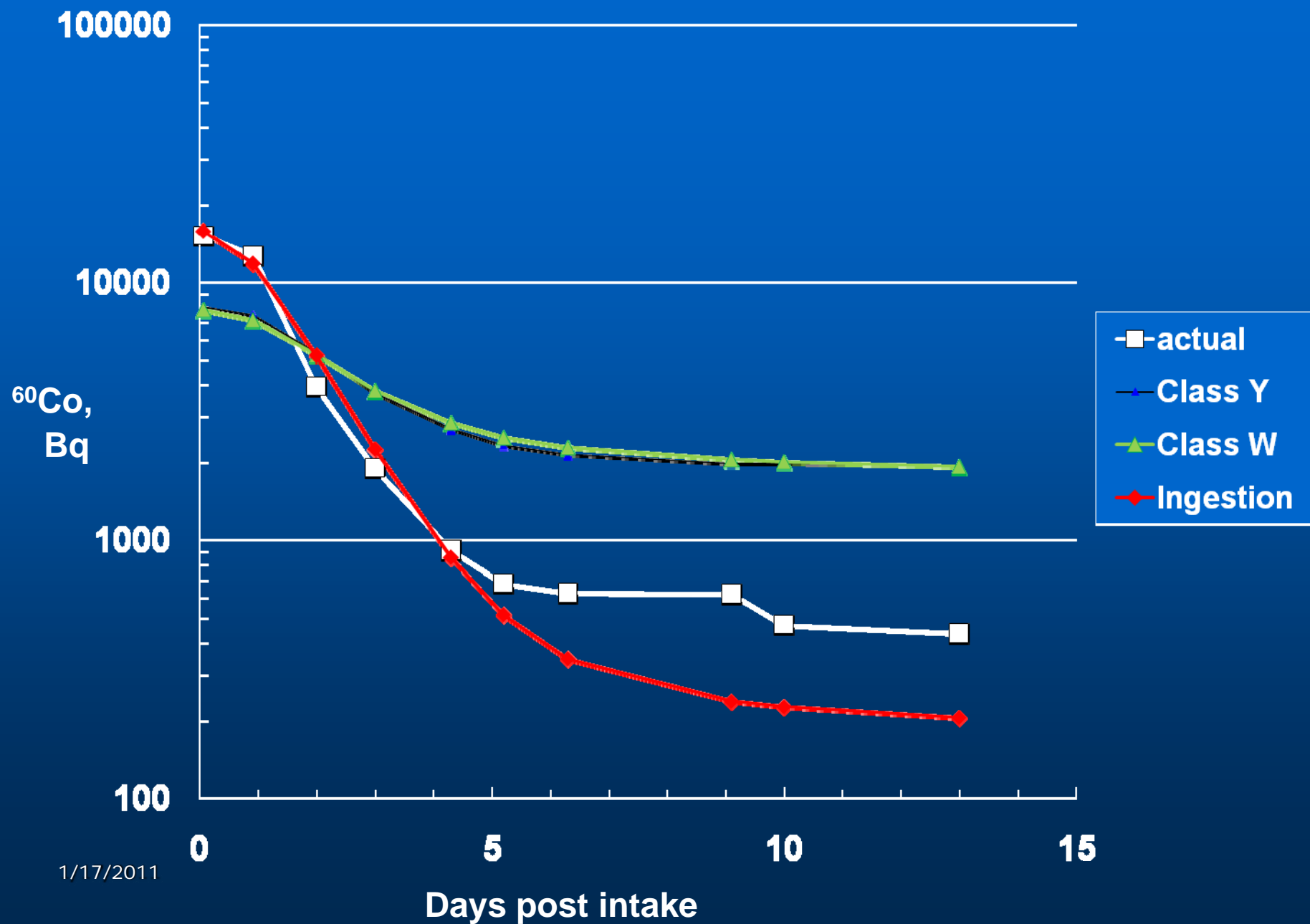
Worker 1 WBC Data



Need for Careful Assessment

- Plant had a history of fuel failure
- Analysis of debris samples showed high α/β activity ratios and various TRU, including ^{238}Pu , $^{239,240}\text{Pu}$, ^{241}Am , and ^{244}Cm
- Initial calculation of CDE to bone surfaces exceeded 1 Sv
- Results from fecal samples for TRU were highly variable

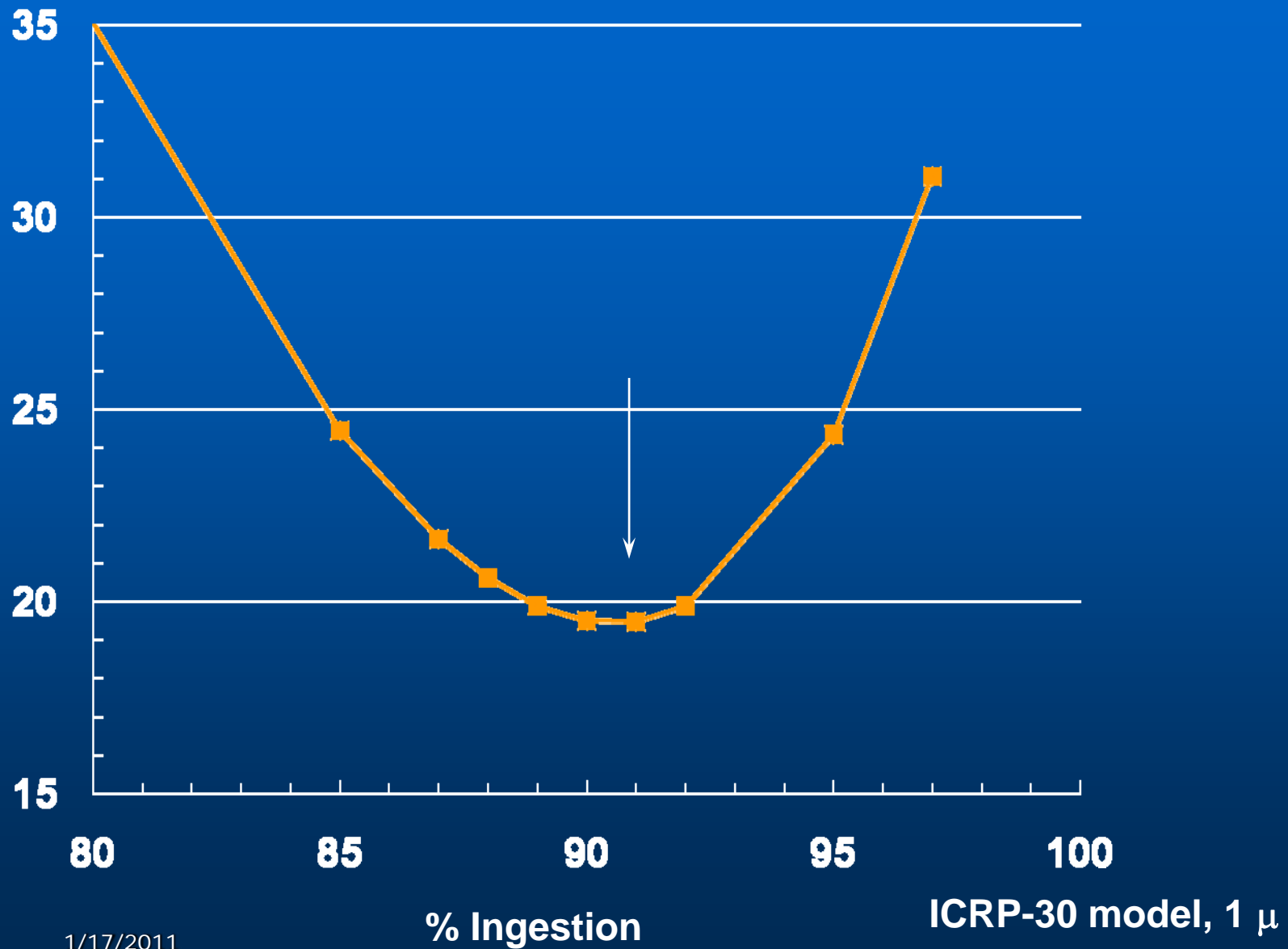
Worker 1: Fits to WBC Data



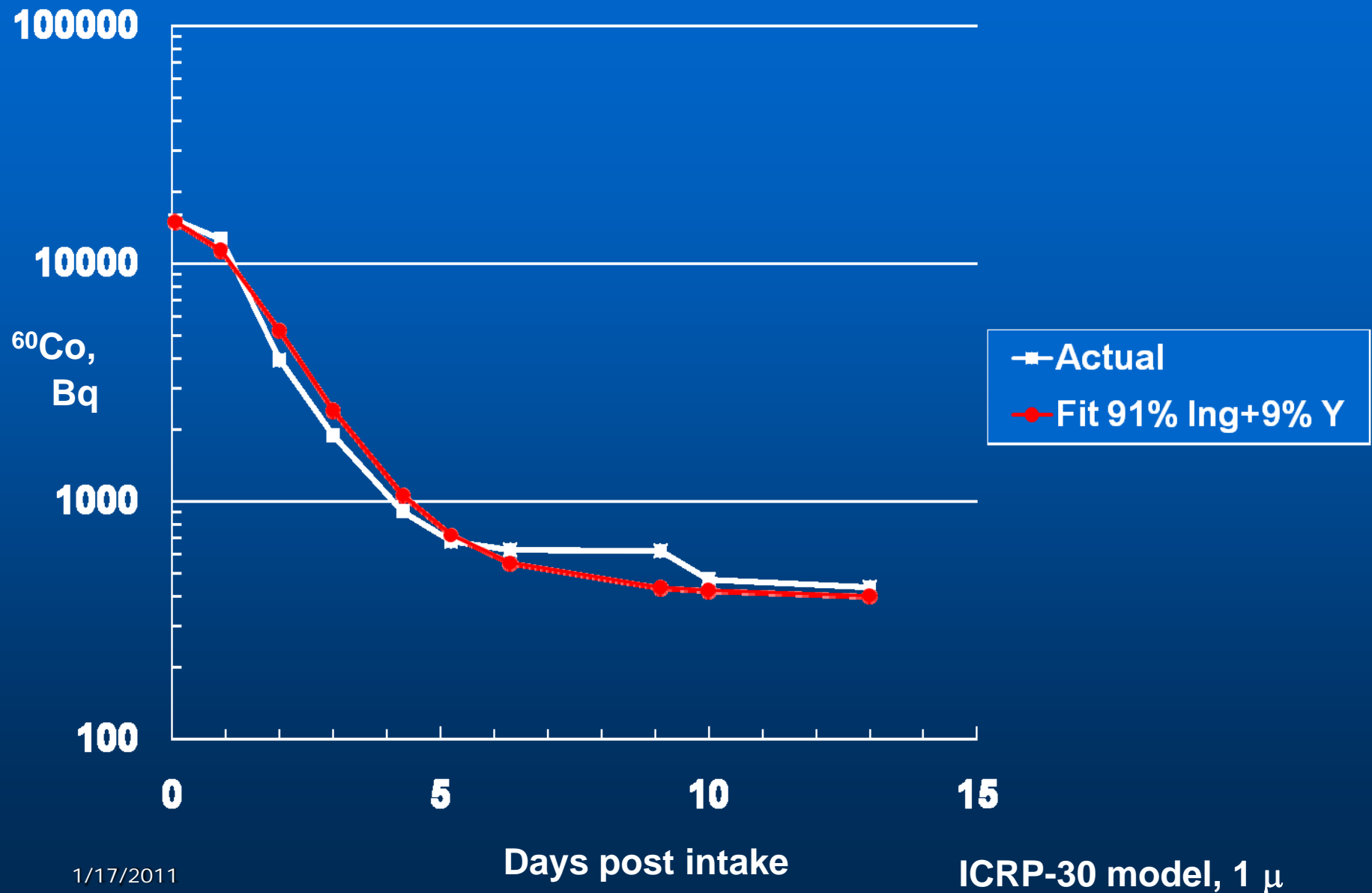
Ingestion vs. Inhalation

- The first comparison of models involved assuming different fractions of inhalation vs. ingestion, e.g.:
 - 100% inhalation
 - 90% inhalation, 10% ingestion
 - 80% inhalation, 20% ingestion
 - etc., etc., etc.
- Using ICRP 30 models, 1 μ AMAD

Worker 1: Summed square deviations vs. ingestion fraction



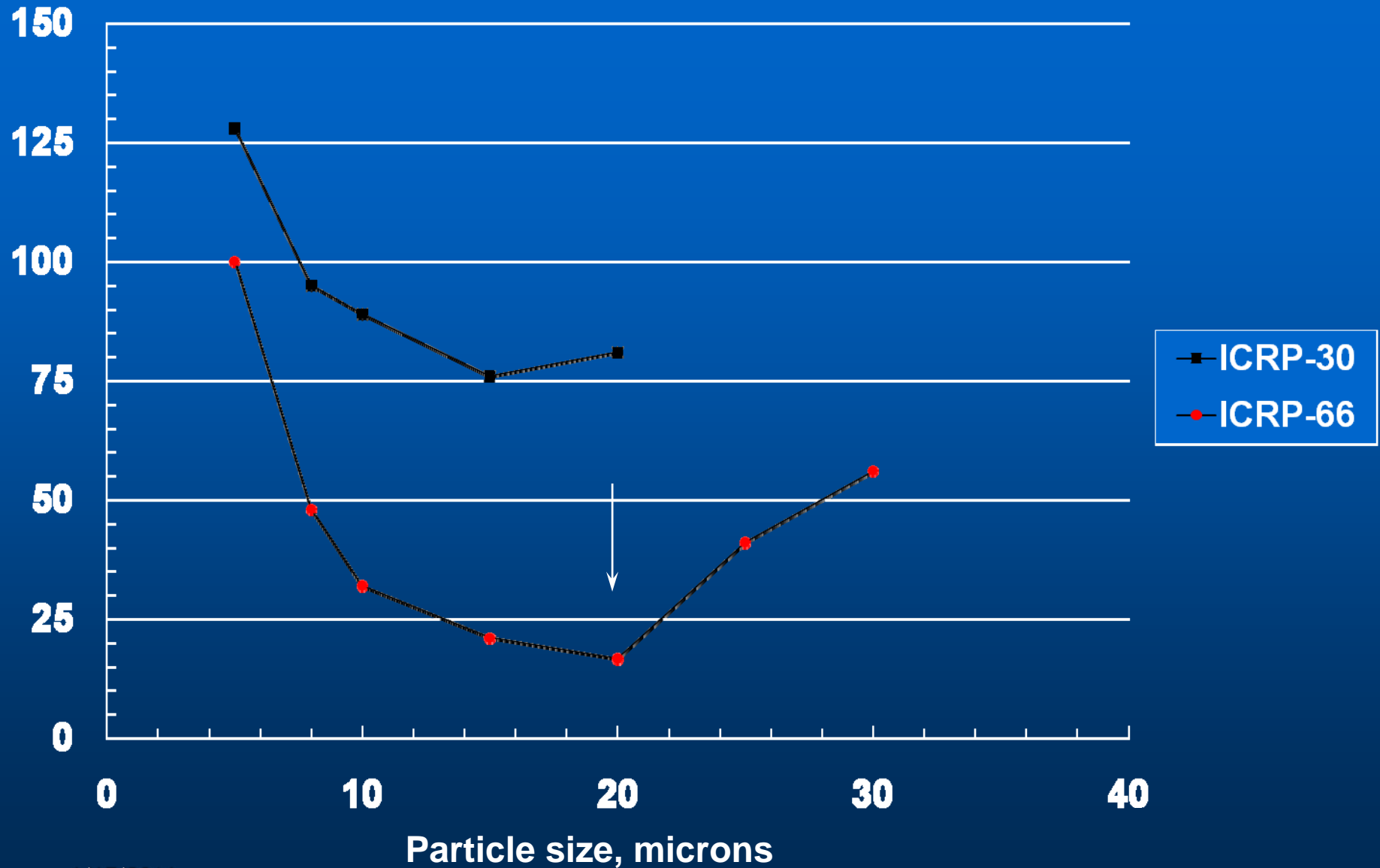
Worker 1: Best fit to WBC Data



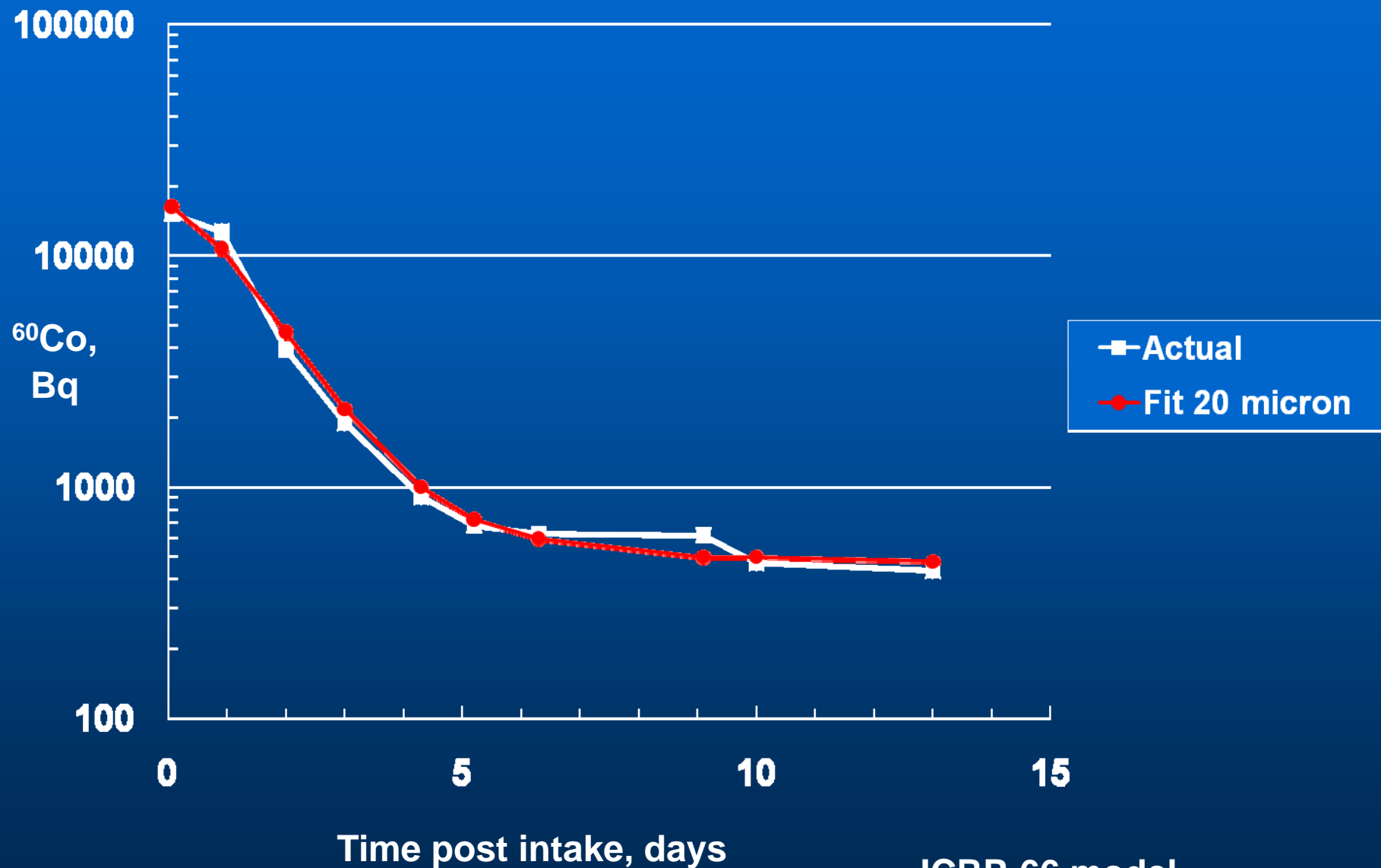
What About Particle Size?

- The combination of inhalation and ingestion could reflect a larger particle size, resulting in greater deposition in the upper respiratory tract, leading to mucociliary clearance and swallowing of inhaled material
- Repeat least squares analysis for 100% inhalation vs. particle size

Worker 1: Summed squared deviations vs. particle size (inhalation only)



Worker 1: Best fit to WBC data, inhalation only



Dose Assessment

- If 1 μ particles, inhalation plus ingestion, ^{60}Co intake = 1.4 kBq inh. + 14 kBq ing. CEDE = 4.4 mSv; CDE (BS) = 77 mSv
- If 20 μ particles, inhalation only, ^{60}Co intake = 400 kBq CEDE = 3.4 mSv; CDE (BS) = 59 mSv
- Dose is almost entirely from TRU

Conclusions

- Accurate intake assessment is needed when TRU nuclides are involved
- More complete fecal sampling (especially at early times) would have helped
- Ease of detection of ^{60}Co by WBC makes it useful as a marker radionuclide
- Only definitive way to characterize intake would be by particle size analysis

Case Study #2

- Two workers at the Hanford site were transferring radioactive waste containing ^{241}Am from a shipping barrel to a disposal container
- The workers were wearing respiratory protection
- A supervisor was also present, and not wearing respiratory protection

Case Study #2, con't

- On exit, all three were found to be contaminated; air samples were later determined to be positive.
- Lung counts were performed the next day; all 3 were positive
- Urine and fecal sample collections also begun
- REAC/TS consulted re chelation Tx

Bioassay results

- Patient #1 (supervisor, male):
 - Lung content: 400 Bq
 - Urine: 1 Bq per day
- Patient #2 (female):
 - Lung content: 200 Bq
 - Urine: 0.12 Bq per day
- Patient #3 (male):
 - Lung content: 50 Bq
 - Urine: 0.06 Bq per day

Intake and effective dose estimates

- Patient #1: 1.8 kBq, 210 mSv
- Patient #2: 0.63 kBq, 73 mSv
- Patient #3: 0.15 kBq, 17 mSv
- Chelation Tx begun on day 2 with Ca-DTPA for the males and Zn-DTPA for the female, and continued daily with Zn-DTPA for 5-6 d
- Bioassay measurements continued

Averted Dose

■ Patient #1:

- w/o DTPA Tx: 210 mSv
- w/ DTPA Tx: 49 mSv

■ Patient #2:

- w/o DTPA Tx: 73 mSv
- w/ DTPA Tx: 38 mSv

■ Patient #3:

- w/o DTPA Tx: 17 mSv
- w/ DTPA Tx: 10 mSv

Long-term Tx

- DTPA therapy discontinued after one week, one administration at day 90, then recommended at day 270
- DTPA effective at removing ^{241}Am from liver
- No further Tx recommended for Pt. #3, additional Tx at day 635 for Pts. #1 & #2, then at day 1000 for Pt. #1
- Pt. #3 was most concerned about discontinued Tx

Case Study #3

- Two separate incidents at LANL involving ^{239}Pu -contaminated puncture wounds to glovebox workers
- Occupational Medicine staff had attended REAC/TS training
- HP staff not familiar with medical protocols

Worker #1

- Worker used a screwdriver inside the glove box to remove a piece of metal from a sample, the sample gave way and he punctured his left index finger
- Worker failed to use PPE, i.e., leather gloves over his glovebox gloves
- Initial survey of wound site showed ~1500 dpm alpha (25 Bq)

Worker #1 Tx

- Initial wound count ~600 Bq; potential effective dose ~ 0.3 Sv if all became systemic
- Wound decontaminated and excised several times
- Residual content ~ 400 Bq
- DTPA Tx: 2x Ca-DTPA and 13x Zn-DTPA over next 30 d
- Day 42: worker requested additional Zn-DTPA Tx

Worker #2

- Worker lacerated right wrist on a cutting tool inside the glovebox while placing cotton gloves over glovebox gloves to prevent sample contamination
- Worker failed to use hazard control, i.e., moving cutting tool out of reach or installing a guard
- Initial survey of wound site showed ~10,000 dpm alpha (170 Bq)

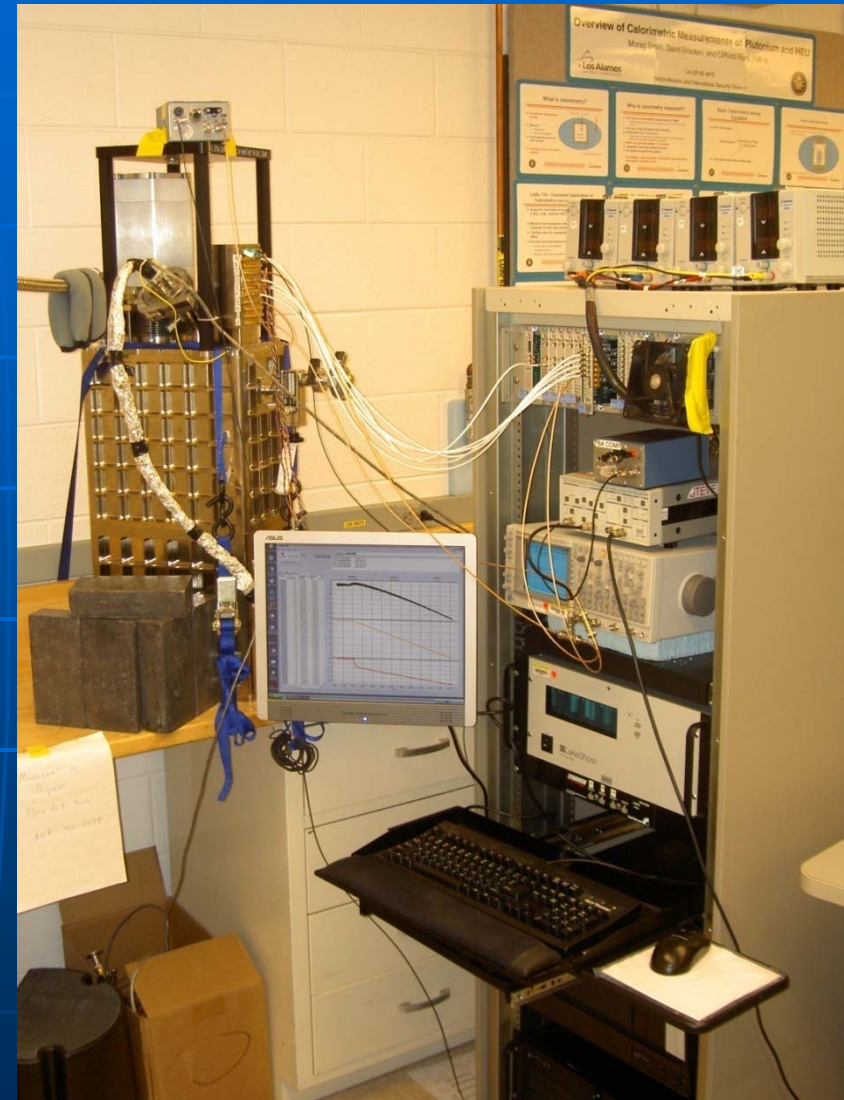
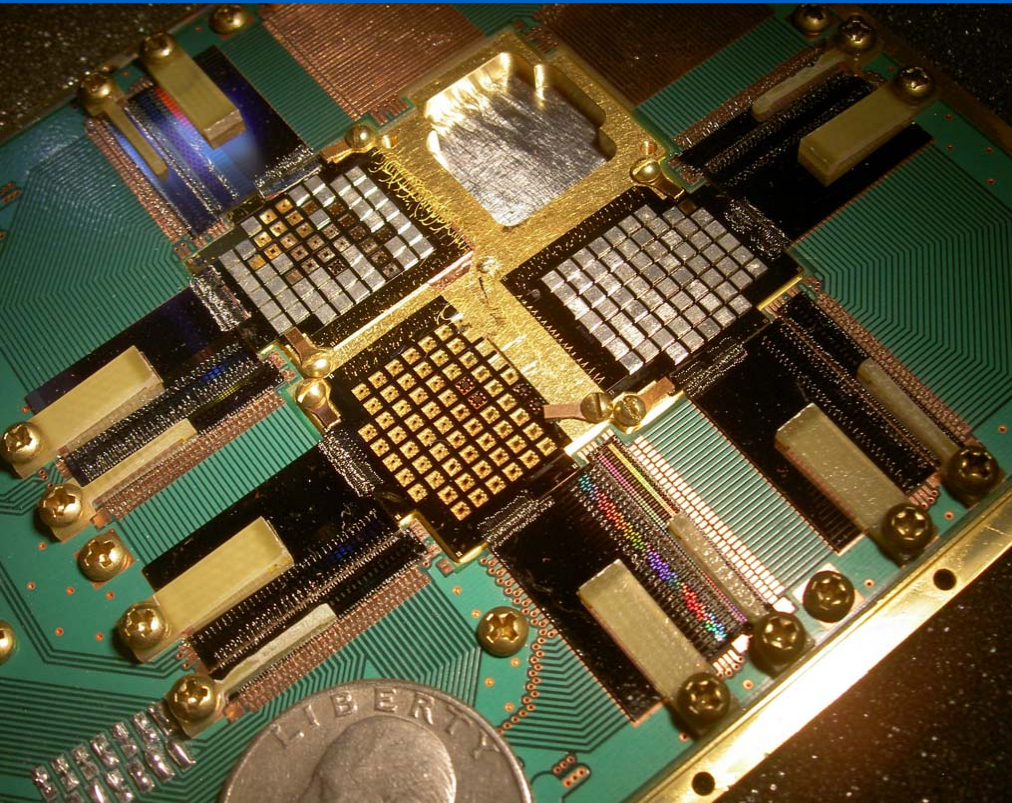
Worker #2 Tx

- Initial wound count ~40 Bq; potential effective dose ~ 20 mSv if all became systemic; threshold for recommending chelation Tx
- Wound decontaminated and excised
- Residual content not detectable
- DTPA Tx: 1x Ca-DTPA
- HP resistance to DTPA Tx; considered unnecessary

Case Study #4: NIST Pu-239 Spill

- The U.S. National Institute for Standards and Technology (NIST) is located in Gaithersburg, MD, outside Washington, D.C.
- NIST also operates a laboratory in Boulder, CO (NIST-B)
- Project involved developing new detector for homeland security applications
- Detector is an array of micro-calorimeters, much like an infrared camera, optimized for 100-keV photons

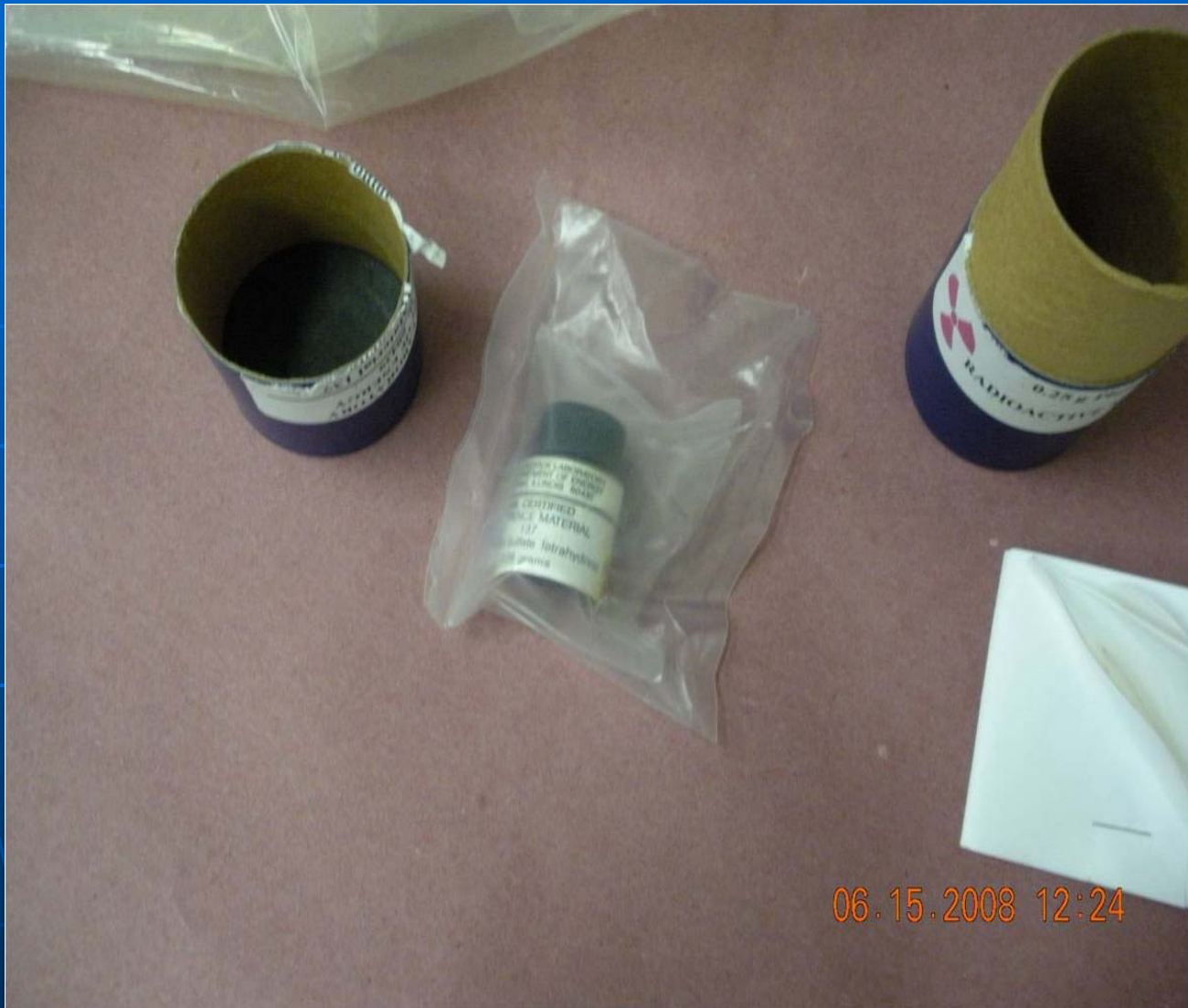
Detector Array



Plutonium Source

- The source was 250 mg of $^{239,240}\text{Pu}$ sulfate tetrahydrate in a glass vial, about the size of a liquid scintillation vial, with a rubber O-ring seal under the screw-on cap; activity ~ 0.6 GBq
- Sample was prepared as Standard Reference Material about 20 years ago by the DOE New Brunswick Laboratory at Argonne

Source Configuration



Incident prologue

- On Friday 6 June Worker #1 and #2 (who had been trained) set up a long weekend run; they noticed varying count rate with source position, so tapped vial on marble bench top to settle powder in one corner
- Worker #1 also set up Pb bricks to shield computer from source to prevent failure from dropped bits he thought were caused by radiation.

Incident

- On Monday June 9, worker #1 was setting up another run and moving source by hand in front of detector while observing count rate on computer and stated he may have tapped the source bottle against one of the Pb bricks.
- Worker #1 stated he then noticed what appeared to be a crack in the bottle, so replaced it in outer plastic bag and source safe, washed his hands, took his notebook to his office, then notified P.I. about 1 hr later

Ruptured Source



Immediate Actions

- P.I. observed “brown powder” inside source bag and also on bench top, and ordered the lab to be evacuated, but workers were told to wait in the hallway for further instructions.
- P.I. notified Group Leader, who came to lab, and advised workers to remove their shoes to avoid spread of contamination

Area Surveys

- Contamination found in hallways, men's room, Worker #1 office, P.I. office, and on shoes and bare feet of workers in hallway outside lab.
- Workers decontaminated and sent home
- Surveys and decon of areas outside the lab continued for several days.

Off-site Release

- The maximum release to the city sewer line was ~ 0.2 GBq
- Given a daily discharge of 450,000 gallons from the site, and a 30-day average, release was within regulatory limits
- However, extensive negative publicity and citizen concern resulted

Initial Bioassay

- Urine samples collected from 21 workers 13-16 June; all results negative except Workers #1 and #2
- Unfortunately, samples were 100-250 mL and analyzed by gross alpha-beta, $DL = 0.4 \text{ mBq/L}$
- 1-liter samples collected week of 23 June for alpha-spec and TIMS

Worker #1 Initial Results

- Urine: 2 mBq/L; intake = 58 Bq;
CED (BS) = 60 mSv
eff. dose = 3 mSv
- Fecal: 9 Bq/d; intake = 56 Bq
- Initial report to REAC/TS was 20 (!) mBq/L, resulting in recommendation for DTPA Tx

Final Bioassay results

- Worker #1 intake = 40 Bq
Eff. Dose = 2 mSv
CED (BS) = 40 mSv
- DTPA TX averted 6 mSv CED (BS)
- Worker #1 had 2 Tx, wanted third

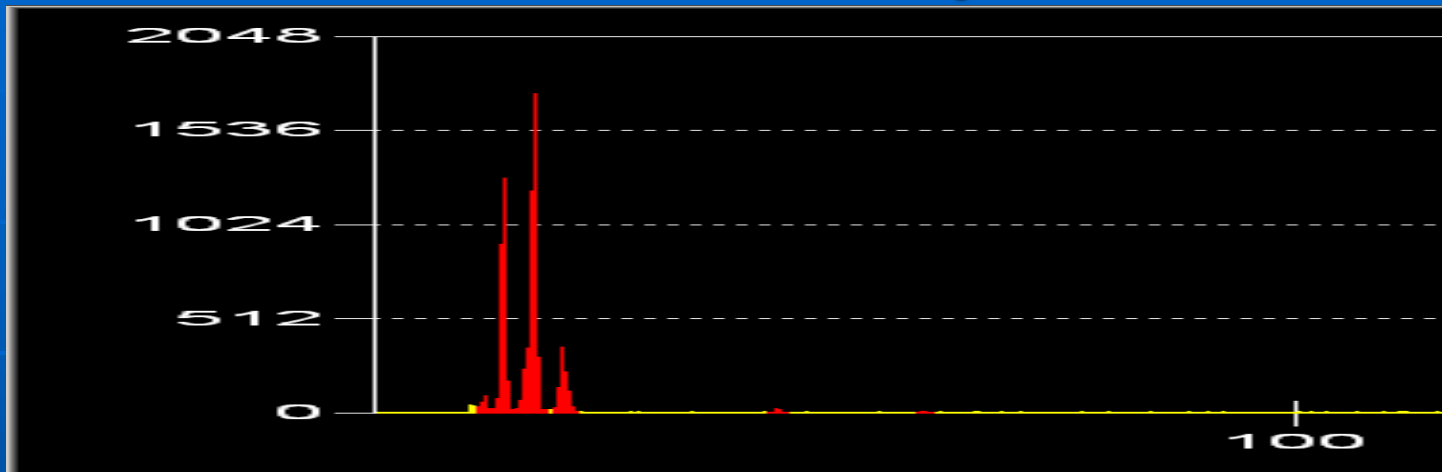
Causes of Incident

- Untrained worker allowed to use source without supervision
- P.I. did not ensure training conducted
- No emergency procedures developed or posted
- Inadequate equipment and trained response personnel on site

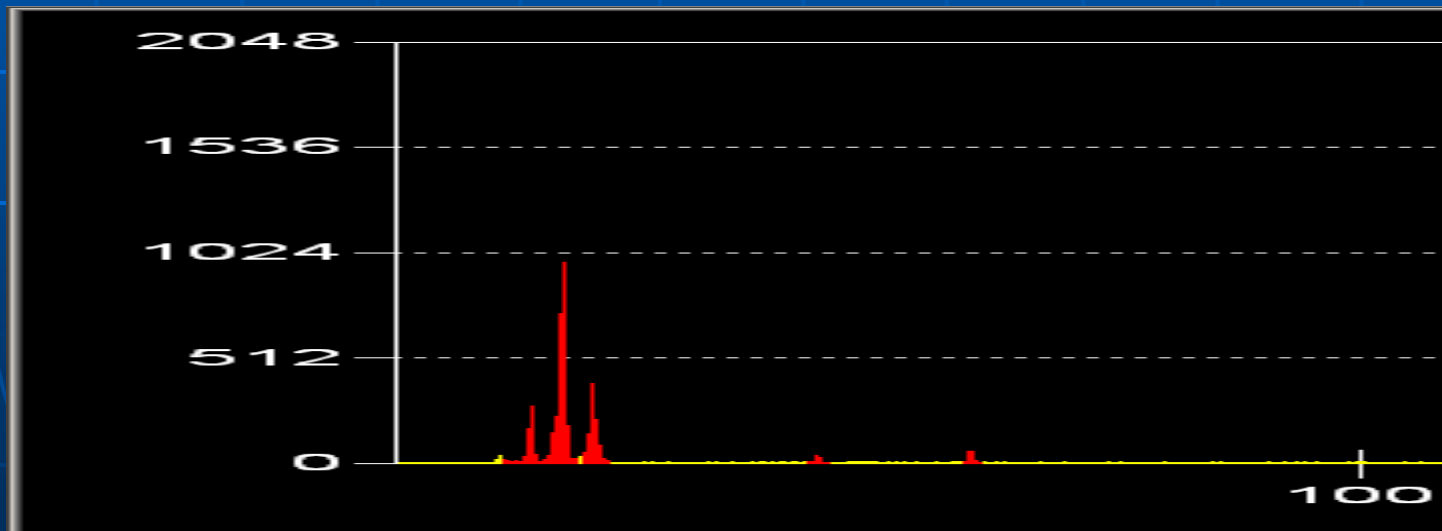
Case #5 Puncture wound

- On 14 June 2010 an individual punctured his right index finger while “flagging” vented cans of legacy waste containing Pu-238
- Cotton liner, 2 pr surgical gloves, nitrile glove, glovebox glove, leather work glove
- Initial wound site contamination levels were 300 dpm alpha (ZnS scintillation probe used)

Wound Counter Spectra

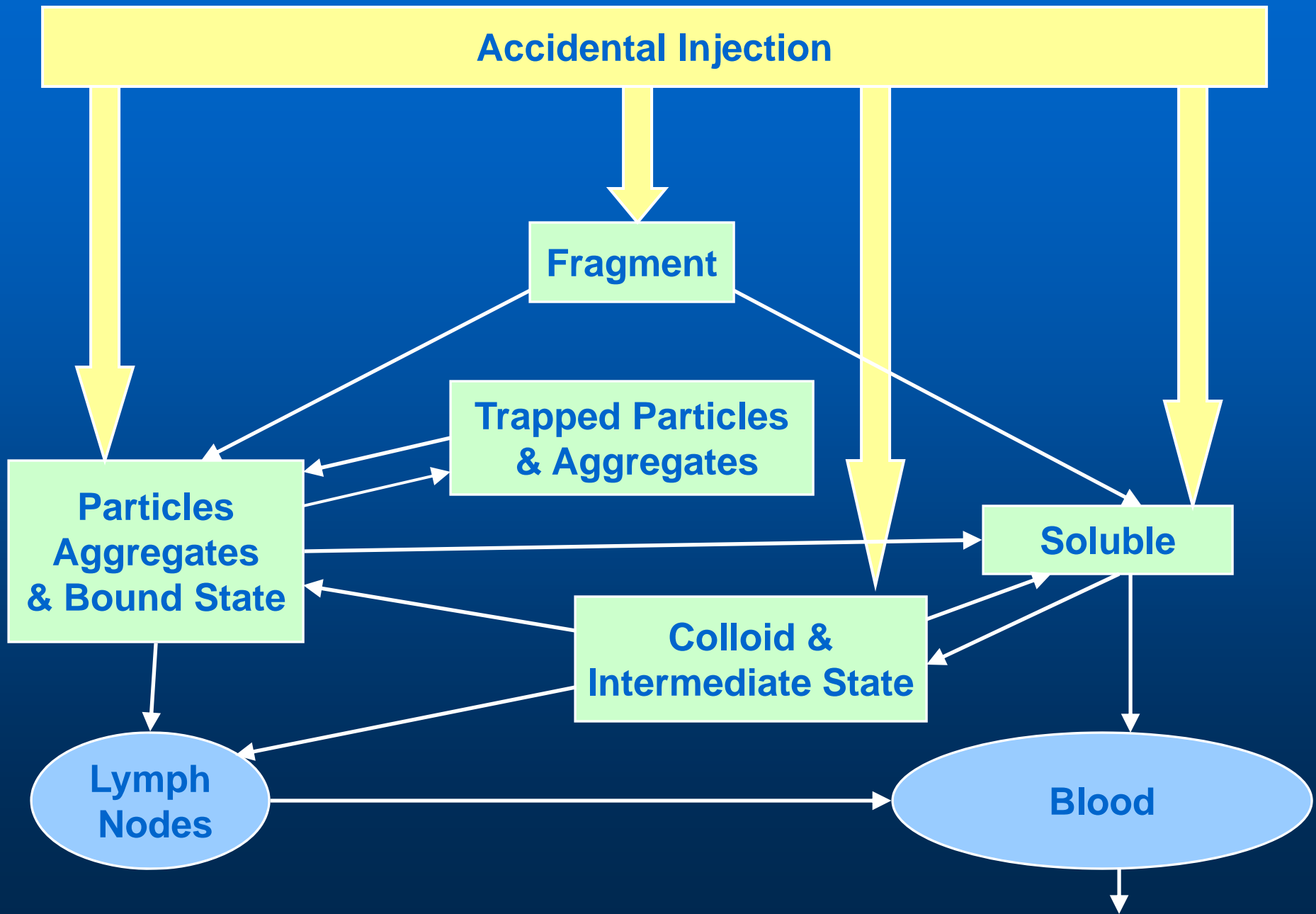


Pu-238 source spectrum

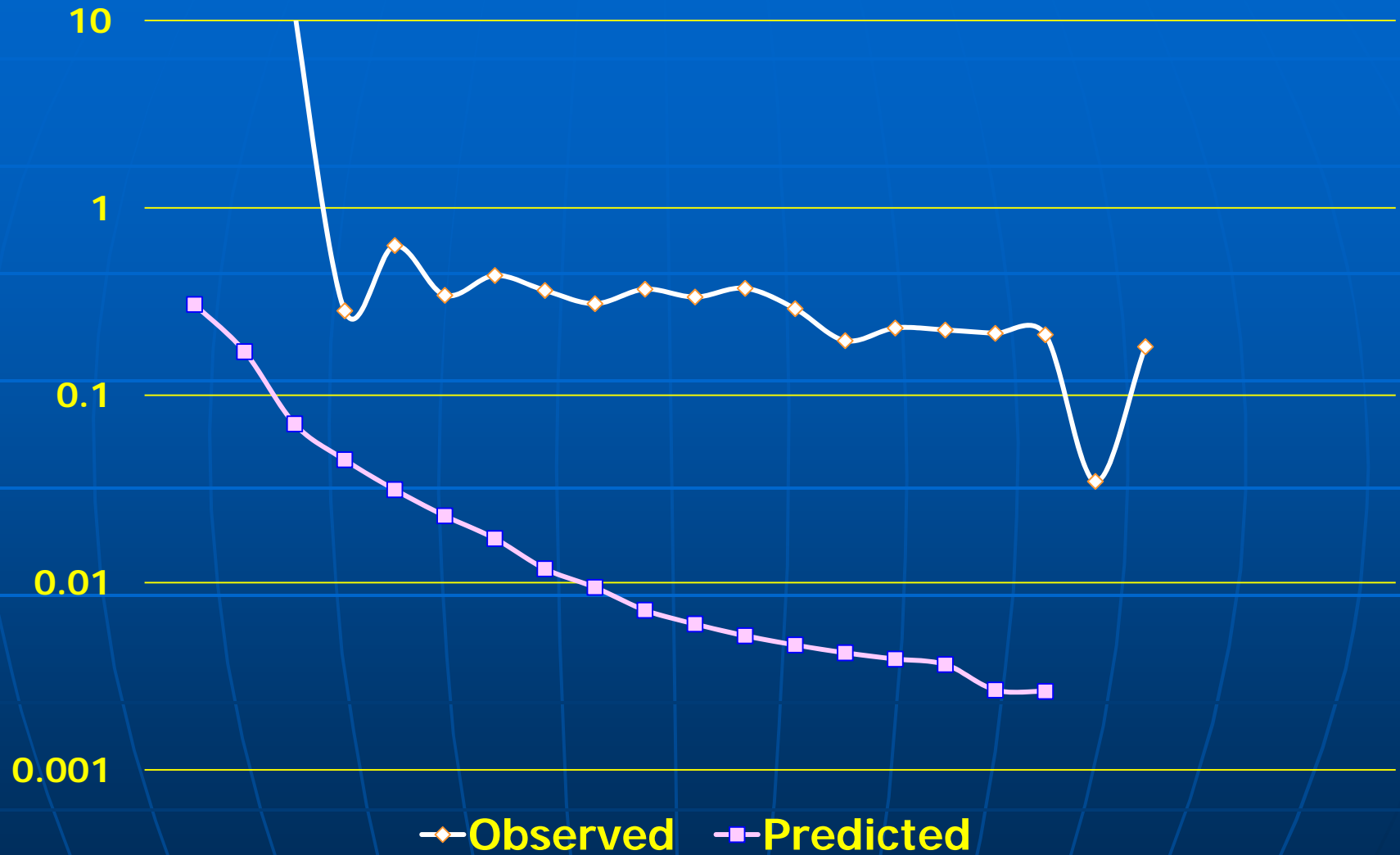


Wound count

THE NCRP WOUND MODEL



Daily Urinary Excretion, nCi



Conclusions

- DTPA has increased urinary excretion by about a factor of forty
- Every week the removal of plutonium by DTPA reduces body content by about 2 nCi and averts several rem of committed effective dose

SUMMARY

- Intakes of transuranics are difficult to quantitate
- ALI values are rather low (several nCi or tenths of kBq)
- Treatment with DTPA is very effective but must be started promptly
- Dose assessment may take months