# INTERNAL DOSIMETRY
# AT RESEARCH AND MEDICAL FACILITIES

The University Five

Case Studies

# Learning Objectives

- Identify radionuclides of concern at research and medical facilities
- Analyze two case studies

# The University Five

- C-14: radiolabeling, radiocarbon dating
- P-32: radiolabeling of biomolecules
  - (also H-3, e.g., tritiated thymidine)
- I-125: diagnostoc nuclear medicine
- I-131: therapeutic nuclear medicine
- Cf-252: neutron sources
  - Not an internal hazard

# H-3, C-14 and P-32

- Low-,Medium- and High-energy beta emitters
- C-14 and P-32 detectable with pancake GM
- Normally quantified by smears and BLS
- Organically bound tritium (OBT): 50 % has a T(b) of 10 d and (50%) has a T(b) of 40 d (same as carbon)
- ALIs: C-14 = 2 mCi, P-32 = 0.9 mCi

# Iodines

- All ALI's (except I-120m, I-128, I-134) are based on non-stochastic limit of 500 mSv CODE to thyroid ($w_T = 0.03$)
- Volatile, so easily dispersed; treatment is usually blocking with stable KI (325 mg); unblocked thyroid deposition = 25%; KI administered within 1-2 minutes lowers to 2%, after 6 hr lowers to 10%, no effect more than 12 hr after intake; however, daily dose prevents re-uptake of circulating iodide
- MDA in thyroid for photon-emitting isotopes is less than 0.4 Bq

# Medical Uses of Radioiodines

- Thyroid uptake studies:
  15 MBq I-123 NaI (3.4 mGy/MBq)
  or 0.4 MBq I-131 NaI (340 mGy/MBq)
- Thyroid scanning:
  4 MBq I-131 NaI p.o. for routine
  75 MBq I-131 NaI for post-operative carcinoma scanning
  Tc-99m $O_4$ actually more common
- Thyroid ablation:
  1.1 GBq I-131 NaI for hyperthyroidism;
  7.4 GBq I-131 NaI for carcinoma
  pregnancy testing always indicated

# Estimates of Intakes and Internal Doses from Ingestion of P-32 at MIT and NIH

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# Introduction

- June 29, 1995 - individual at NIH reportedly internally contaminated with P-32
- August 14, 1995 - individual at MIT also reported to have intake of P-32
- Internal Dose Center at Oak Ridge contacted for technical support
  - General internal dose information support center
  - Subcontractor to the USNRC - role in assessment of accidental intakes of radionuclides
  - Association with REAC/TS

# Introduction (cont'd)
# MIT Intake Incident

- Researcher working with P-32 - labeling of DNA components
- Contamination discovered early - external contamination
- Whole body counting
  - Shielded chair type NaI detector system
  - Started within ~5 days post intake
  - Continued to ~50 days post intake

# Introduction (cont'd)
# MIT Intake Incident

- Urine samples (mostly 24-hr)
  - Liquid scintillation counting
  - Started within ~10 days post intake
  - Continued to ~60 days post intake
- Single set of whole body counting data (N=35)
- Three separate sets of urine data analyzed
  - Supplied by MIT (N = 40)
  - Provided by the researcher (N = 48)
  - Independently analyzed by laboratories at ORISE (N = 51) (2 duplicate samples)

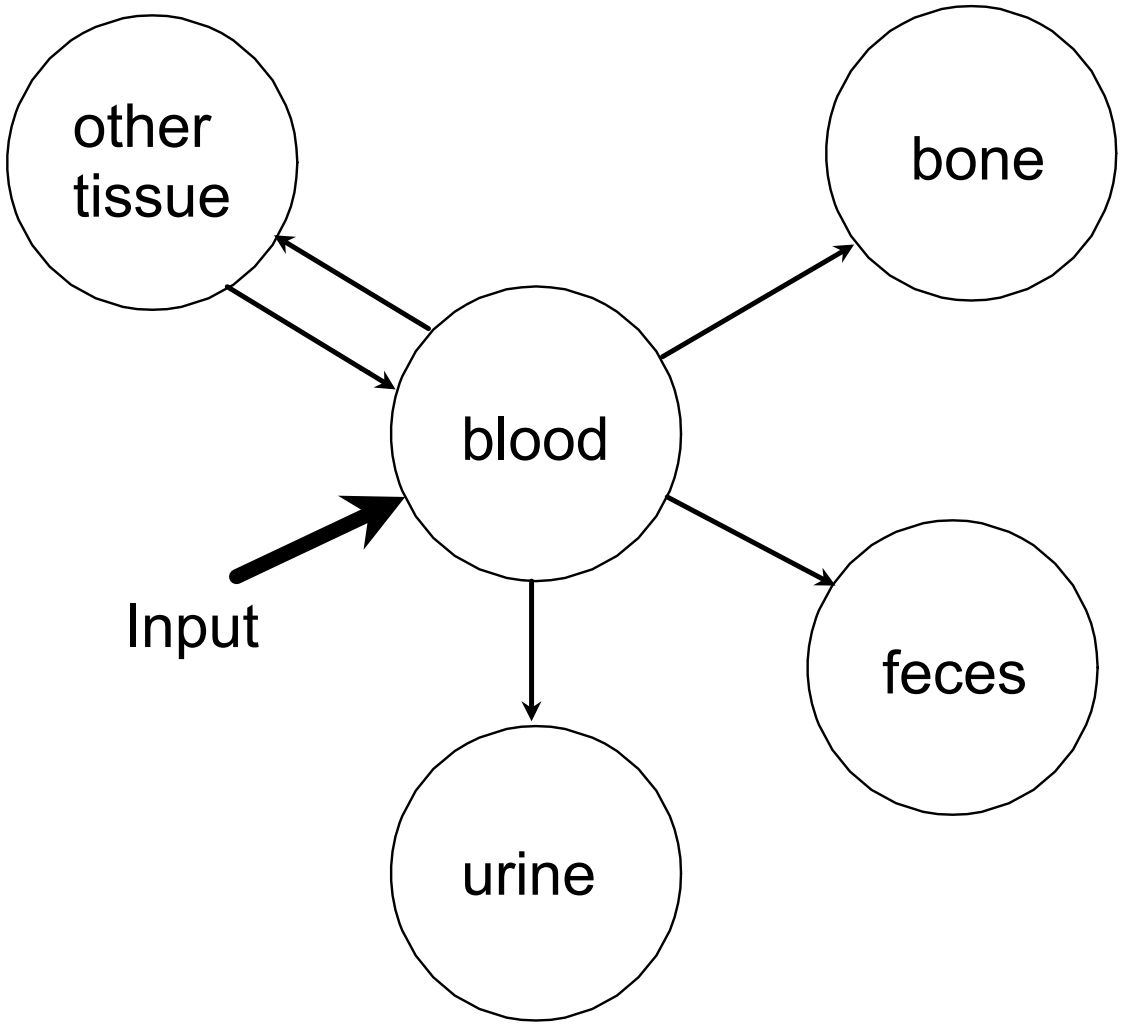
# Methods
# MIT Intake Incident

- Dose Assessment
  - Based on data from site, intake assumed to be ingestion
  - Only one $f_1$ category - licensee suggested that this was reasonable
  - Intake estimates using both weighted and unweighted least squares techniques for single intake/multiple bioassay data points
  - NUREG/CR-4884 used as source of IRFs for whole body retention, 24-hr urinary excretion

# Methods (cont'd) -MIT Intake Incident

- Dose conversion factors from ICRP 30 applied to intake estimates
- Because of slight divergence of model from data at late times, an individual-specific model was also developed
  - Compartmental model developed
  - Whole body and urine data fitted - all model parameters allowed to vary
  - Intake estimated
  - Time integrals of activity in compartments used with ICRP 30 SEEs to obtain dose estimates

# Individual-Specific Kinetic Model



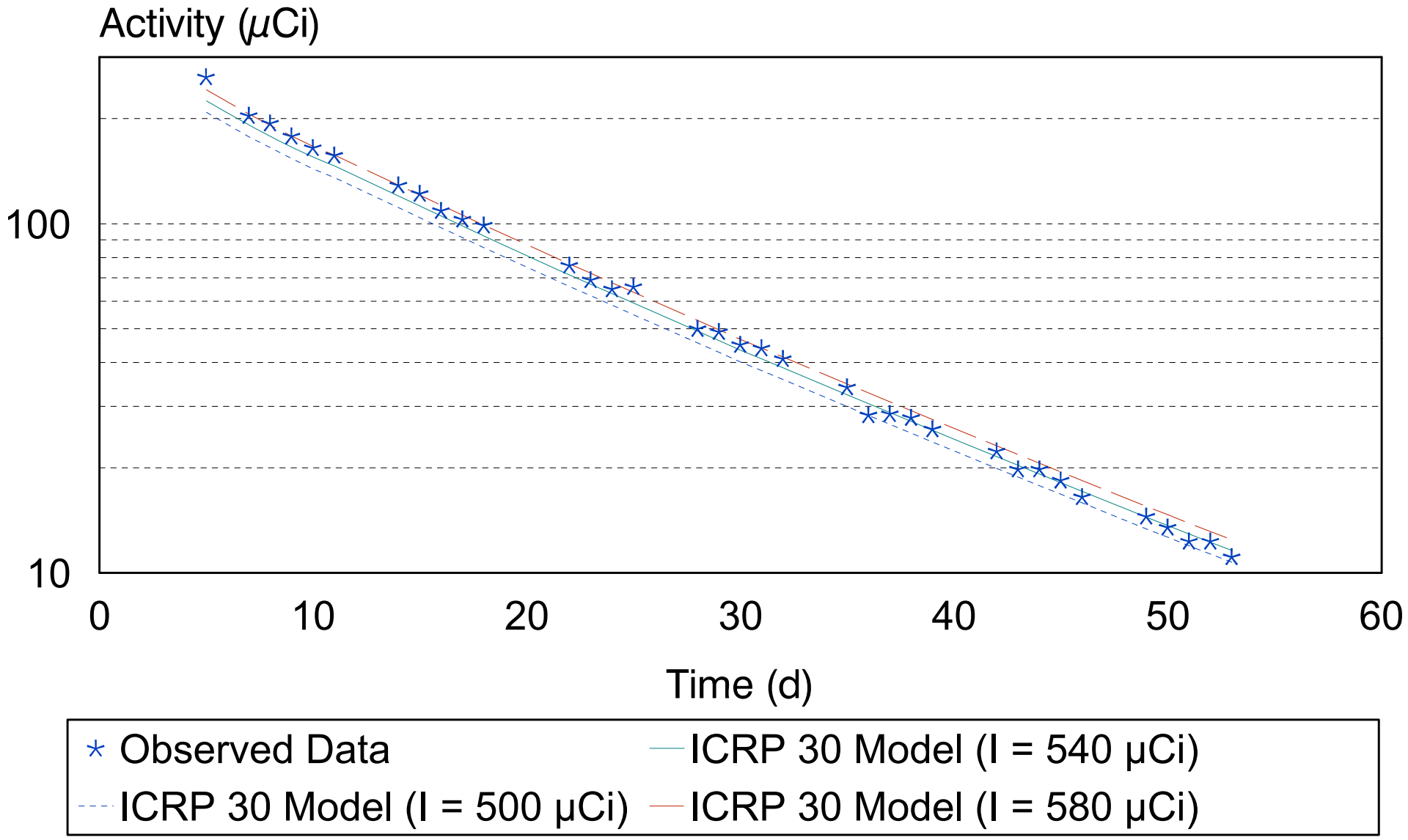
# Methods (cont'd) -MIT Intake Incident

- Individual-specific modeling (cont'd)
  - Doses from intake with standard ICRP 30 model compared with those from the individual-specific model
  - Doses also compared with those predicted by the MIRDOSE 3.1 software program - less conservative marrow dose model
  - Organ doses, Effective Dose Equivalent, Effective Dose calculated

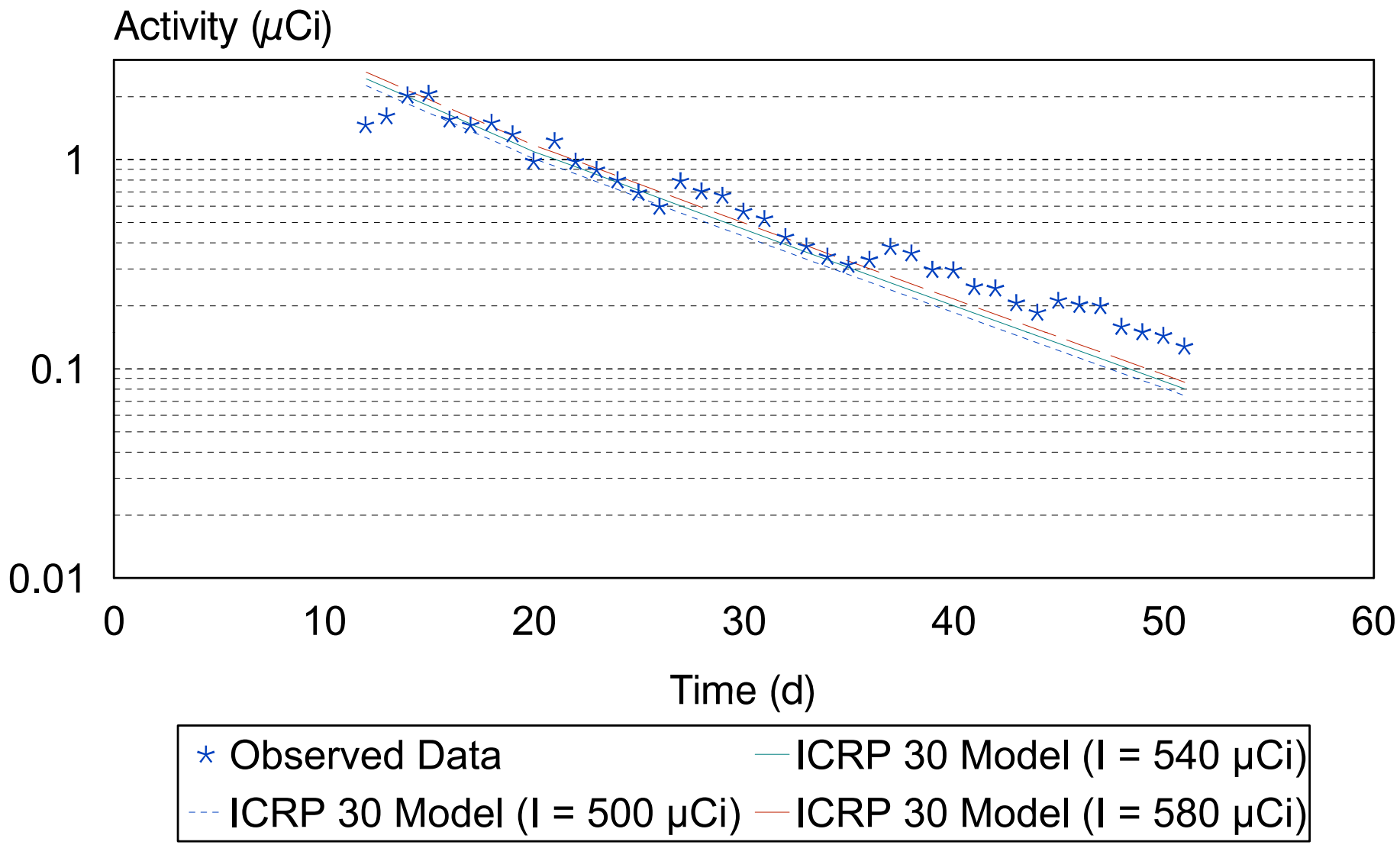
# Results - Intake Estimates (µCi)
# MIT Intake Incident

| | Unweighted | Weighted |
|---|---|---|
| **Whole Body Counting** | 586 | 576 |
| **Urine - MIT** | 505 | 561 |
| **Urine - Researcher** | 522 | 538 |
| **Urine - ORISE** | 484 | 537 |

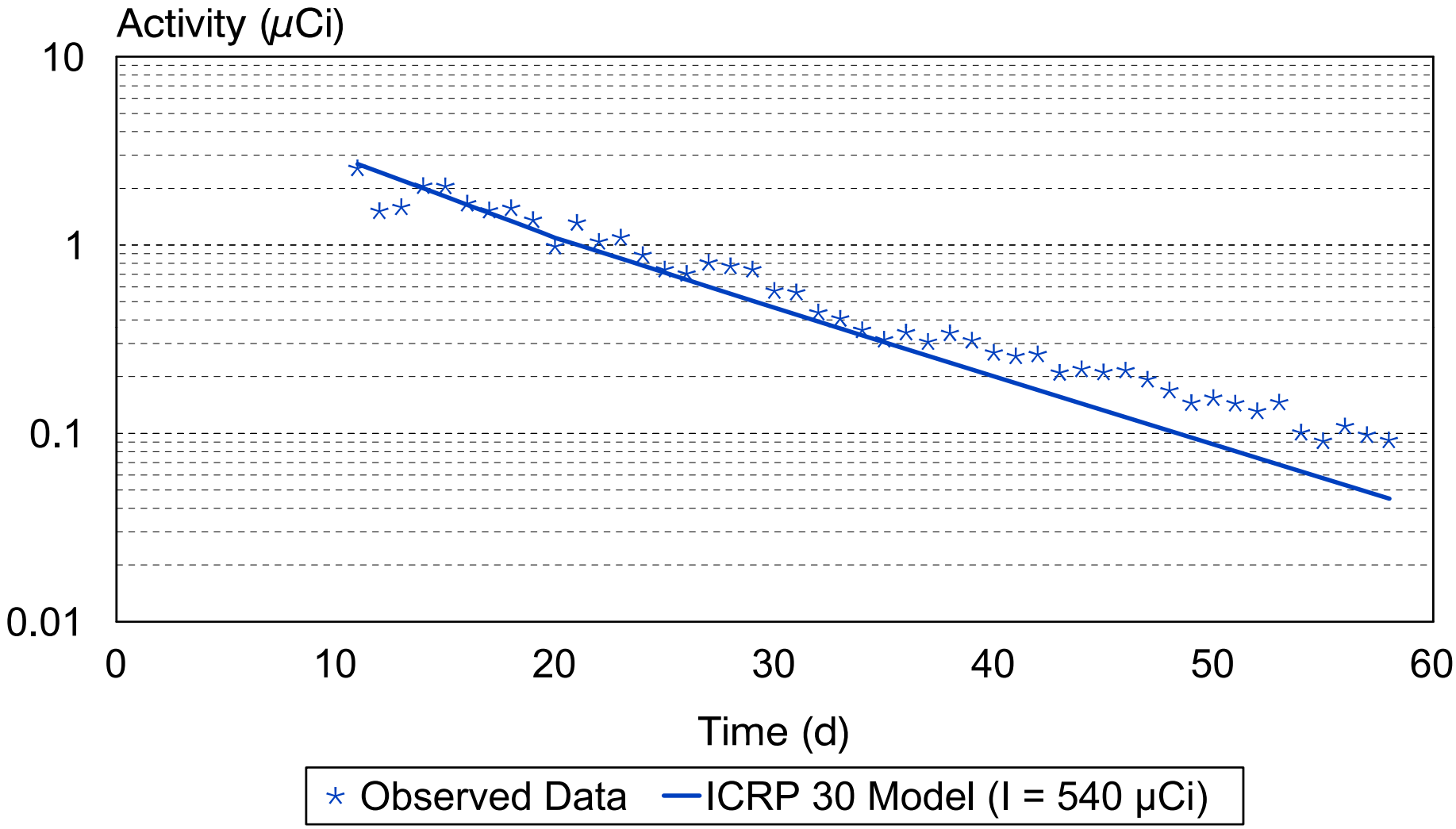
# MIT P-32 Intake - WB Counting Data



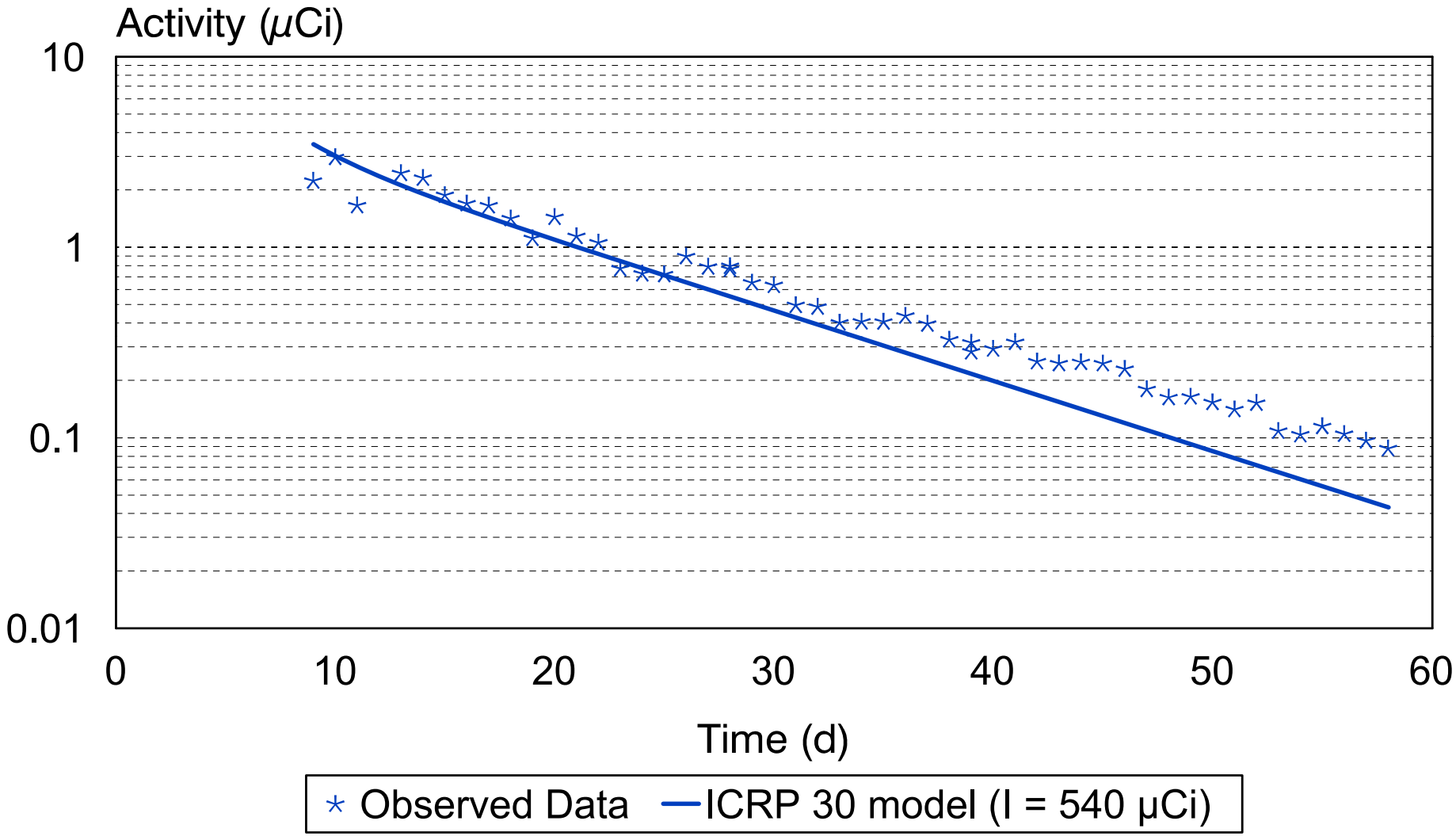
# MIT P-32 Intake - Urine Data (MIT)



# MIT P-32 Intake - Urine Data (Contaminated Individual)



# MIT P-32 Intake - Urine Data (ORAU Analysis)



# Results - Individual-Specific Kinetic Model
# MIT Intake Incident

| | **T = 2.2 days** | **T = 25.5 days** | **T = Infinity** |
|---|---|---|---|
| **Blood** | 0.882 | 0.118 | 0 |
| **Other Tissue** | -0.495 | 0.495 | 0 |
| **Bone** | -0.077 | -0.122 | 0.199 |
| **Total** | 0.31 | 0.491 | 0.199 |

## Results - Committed Doses
## MIT Incident - Effect of Change in Kinetic Model

| | CDE (Sv/Bq) | CDE (Sv) | CDE (Sv/Bq) | CDE (Sv) |
|---|---|---|---|---|
| **Gonads** | 6.5E-10 | 0.013975 | 9.6E-10 | 0.02064 |
| **Breast** | 6.5E-10 | 0.013975 | 9.6E-10 | 0.02064 |
| **Red Marrow** | 8.1E-9 | 0.17415 | 3.9E-9 | 0.08385 |
| **Bone Surfaces** | 7.9E-9 | 0.16985 | 3.8E-9 | 0.0817 |
| **ULI Wall** | 3E-9 | 0.0645 | 4.5E-9 | 0.09675 |
| **LLI Wall** | 7.2E-9 | 0.1548 | 1.1E-8 | 0.2365 |
| **EDE** | 2.1E-9 | 0.04515 | 1.9E-9 | 0.04085 |
| **ED** | 2.1E-9 | 0.04515 | 2E-9 | 0.043 |

## Results - Committed Doses

### MIT Intake Incident - Effect of Change in DCFs

| | CDE (Sv/Bq) | CDE (Sv) | CDE (Sv/Bq) | CDE (Sv) |
|---|---|---|---|---|
| **Gonads** | 9.6E-10 | 0.02064 | 9.9E-10 | 0.021285 |
| **Breast** | 9.6E-10 | 0.02064 | 9.9E-10 | 0.021285 |
| **Red Marrow** | 3.9E-9 | 0.08385 | 3E-9 | 0.0645 |
| **Bone Surfaces** | 3.8E-9 | 0.0817 | 3.5E-9 | 0.07525 |
| **ULI Wall** | 4.5E-9 | 0.09675 | 3.8E-9 | 0.0817 |
| **LLI Wall** | 1.1E-8 | 0.2365 | 1E-8 | 0.215 |
| **EDE** | 1.9E-9 | 0.04085 | 1.7E-9 | 0.03655 |
| **ED** | 2E-9 | 0.043 | 1.9E-9 | 0.04085 |

# Discussion
# MIT Intake Incident

- A large amount of data was available for analysis.
- All of the urine data were in good agreement.
- In general, the agreement of the data with the ICRP model was good.
- The range of estimates of intake from all sources (whole body counting data and urine data) was very small - good confidence in results.
- At late times, the ICRP model appeared to slightly overpredict whole body retention and underpredict excretion

# Discussion (cont'd)
# MIT Intake Incident

- With the individual-specific model, the long term biological half-time appeared to be around 26 d.
- The bone uptake was only about 20%, instead of 30%.
- The predictions of the internal workings of the compartment model are not very reliable, as no data on bone or soft tissue uptake per se was available, only whole body retention and excretion.
- In any case, the most likely intake appears to be around 15 kBq (540 µCi) and the dose about 40-45 mSv (4-4.5 rem).

# Introduction
# NIH P-32 Contamination Incident

- Pregnant researcher (~17 weeks gestation) discovered to be contaminated - internal contamination suspected.
- Conditions of intake difficult to determine.
- Spot urine sample taken immediately, follow-up with many urine samples (mostly 24-hr).

# Introduction
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# Introduction
# NIH P-32 Contamination Incident

- Liquid scintillation counting
  - Started on the day that the contamination was discovered
  - Continued for 29 days
- Two whole body images taken with a nuclear medicine camera and quantitated.

# Introduction
# NIH P-32 Contamination Incident

- 26 other workers contaminated, but at much lower level.
  - 1-3 urine samples taken, liquid scintillation counting
  - Intakes assumed to come from contaminated water cooler.

# Introduction
# NIH P-32 Contamination Incident

- Single researcher - intake assumed to be ingestion
  - Intake from water cooler?
  - Contaminated food?
  - Intentional/accidental?

# Methods
## NIH P-32 Contamination Incident

- Intake form also assumed to be phosphate, due to lack of knowledge of true form. First few samples' kinetics not inconsistent with this model.
- Intake estimates using weighted, unweighted least squares, using NUREG/CR-4884 IRFs for urinary excretion.

# Methods
# NIH P-32 Contamination Incident

- Most samples assumed to be 24-hr values.
  - Highly variable volumes. Some suggestion that fluids were being forced.
  - Times of collection not always 24 hour periods. Some adjustments made to make samples as close as possible to 24-hr samples.
- ICRP 30 DCFs.

# Results
# NIH P-32 Contamination Incident

- In vivo images - 32 MBq (862 μCi) on 6/30, 13 MBq (342 μCi) on 7/7.
- Early estimate of intake, from first 4 data points, was 9.6 MBq (260 μCi), but final estimate, with 10 data points, was 27-30 MBq (740-820 μCi).
- Using a 70 kg adult, this implies a CEDE of 58-64 mSv (5.8-6.4 rem).
- Using a 57 kg adult, this implies a CEDE of 72-80 mSv (7.2-8.0 rem).

# Results
# NIH P-32 Contamination Incident

- Biological half-time from data apparently about 18.3 days. Good agreement with ICRP 30 phosphate model.
- Based on model in NUREG/CR-5631, Rev. 2, dose to fetus at 120 days' gestation about 2.1 mSv/MBq (7.8 rem/mCi). Intake of 27 MBq implies a fetal dose of 57 mSv (5.7 rem).