Heavy Metal and Radionuclide Bioavailability from Savannah River Site Soils

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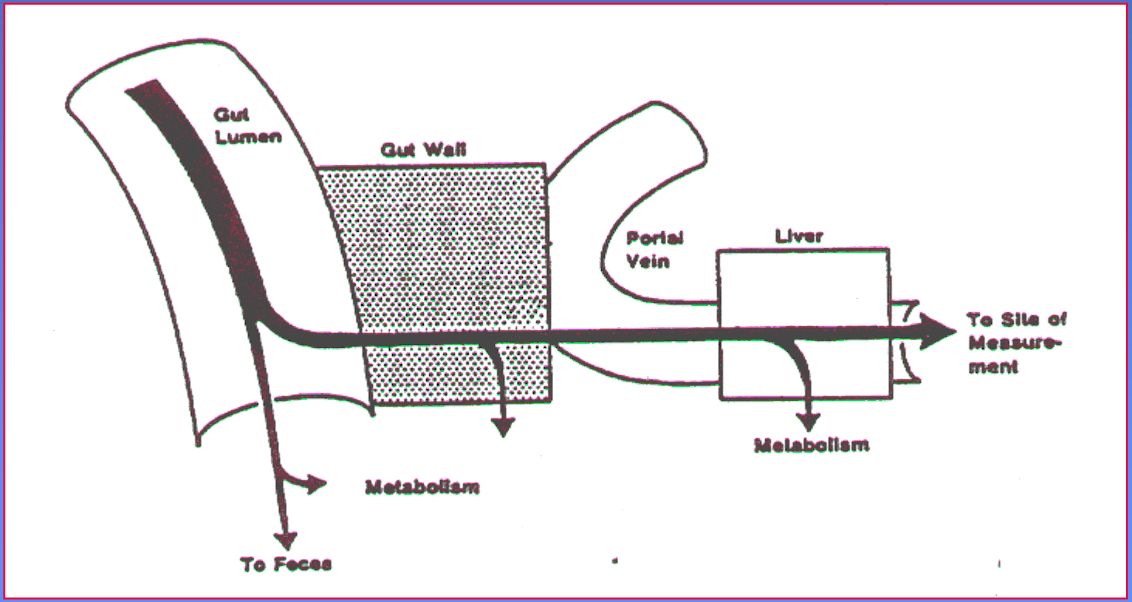
Absorption and Bioavailability

Risk assessments of contaminated soils are more accurate when based upon the bioavailable fraction of a toxicant in a site-specific soil.

- Absorption encompasses all processes from site of administration to site of measurement.
- Bioavailability characterizes the rate and extent of absorption[1].



[1]Gibaldi and Perrier, 1975

Bioaccessibility of Inorganics in Soil

- **Oral bioavailability**:
  - defined as the fraction reaching the systemic blood from the gastrointestinal tract[1]
  - differences between absorption of organic and inorganic species:
    - inorganics are not metabolized
    - inorganics may be transported by metallothionein
  - The factors limiting bioavailability of inorganics are:
    - gastrointestinal dissolution
    - absorption through the intestinal mucosa
- **Bioaccessibility:**
  - defined as the soluble fraction in gut lumen (available for absorption through the intestinal wall)

[1]Ruby, et al. 1999

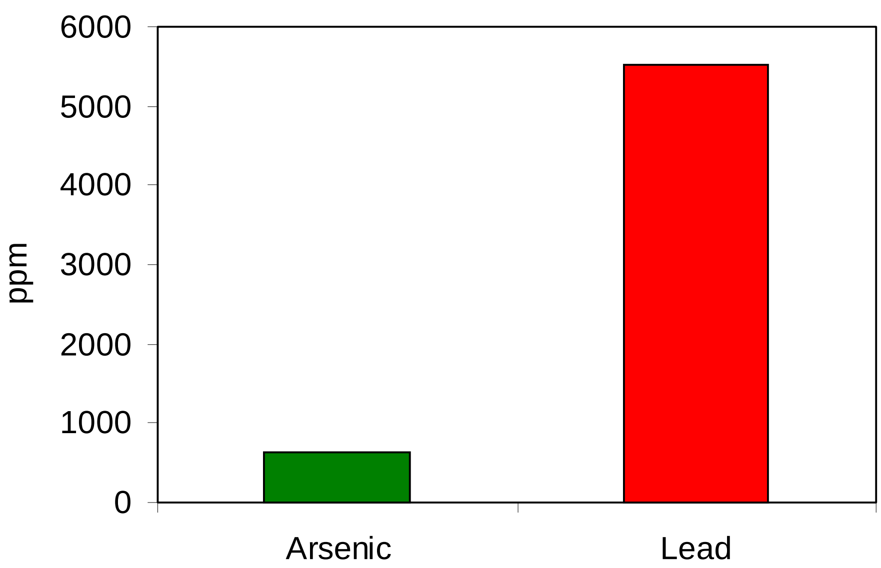
Estimation of Oral Bioavailability

- 200-250g Male Sprague-Dawley rats housed in metabolism cages
- Animals fasted for 24 hours
- Single dose of soil in a 5% gum arabic solution (4g/kg, p.o.)
- Animals sacrificed at 24, 48, 72, or 96 hours
- Urine and feces collected on day of sacrifice
- Target tissues (blood, liver, lung, kidney, spleen, brain, hair, bone, testes, muscle and heart)
- Nitric acid digestion of tissues and excrement
- Analysis for selected metals by ICP-MS

Bioavailability and Bioaccessibility Comparison in a Standard Soil

Results

Total Metal



Bioaccessibility/Bioavailability

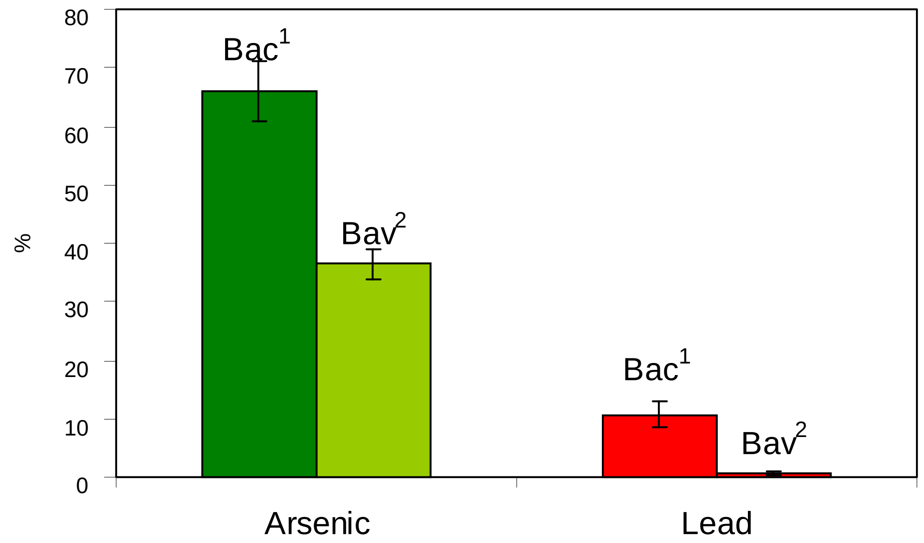


Figure 3a. NIST certified metal concentrations are plotted by metal ppm (ug/g).

Figure 3b. Bioaccessibility[1] and Bioavailability[2] values from Table 3 are plotted by metal.

Consortium for Risk Evaluation with Stake Holder Participation (CRESP)

- Origin of soil samples for this study
- Began in 1995 through a competitive cooperative agreement: DOE

- A key purpose of CRESP is to test the viability of the 1994 National Academy of Sciences' conclusion[1].........

  "The Environmental Management Office of DOE needs an independent institutional mechanism to develop data and methodology to make risk a key part of its decision making."

- CRESP Research Groups involved with this study
  - Exposure Assessment
  - Remediation Technology

[1]www.cresp.org

Bioavailability Research

- **Purposes**
  - Quantification and reduction of uncertainty in the sequence of processes and events leading to exposure to soils at SRS
  - Assess risk of adverse health effects based upon the bioavailable fraction of the contaminant in an environmental matrix
- **Specific Aims**
  - What are the ranges of bioaccessibility of the heavy metals and radionuclide contaminants from a single contaminated site?
  - What are the ranges of bioaccessibility of the heavy metal and radionuclide contaminants from different contaminated sites?
  - What factors can be used to explain variability in bioaccessibility? (pH, CEC, organic mattter, particle size distribution)
  - What is the contribution of the potential exposures to populations currently living or potentially living around a site in the future?

Radionuclide Methods

- **Dried soils to constant weight at 70°C**
- **Soils sieved to d<250um.**
- **Gastric/intestinal fluid extraction (37°C):**

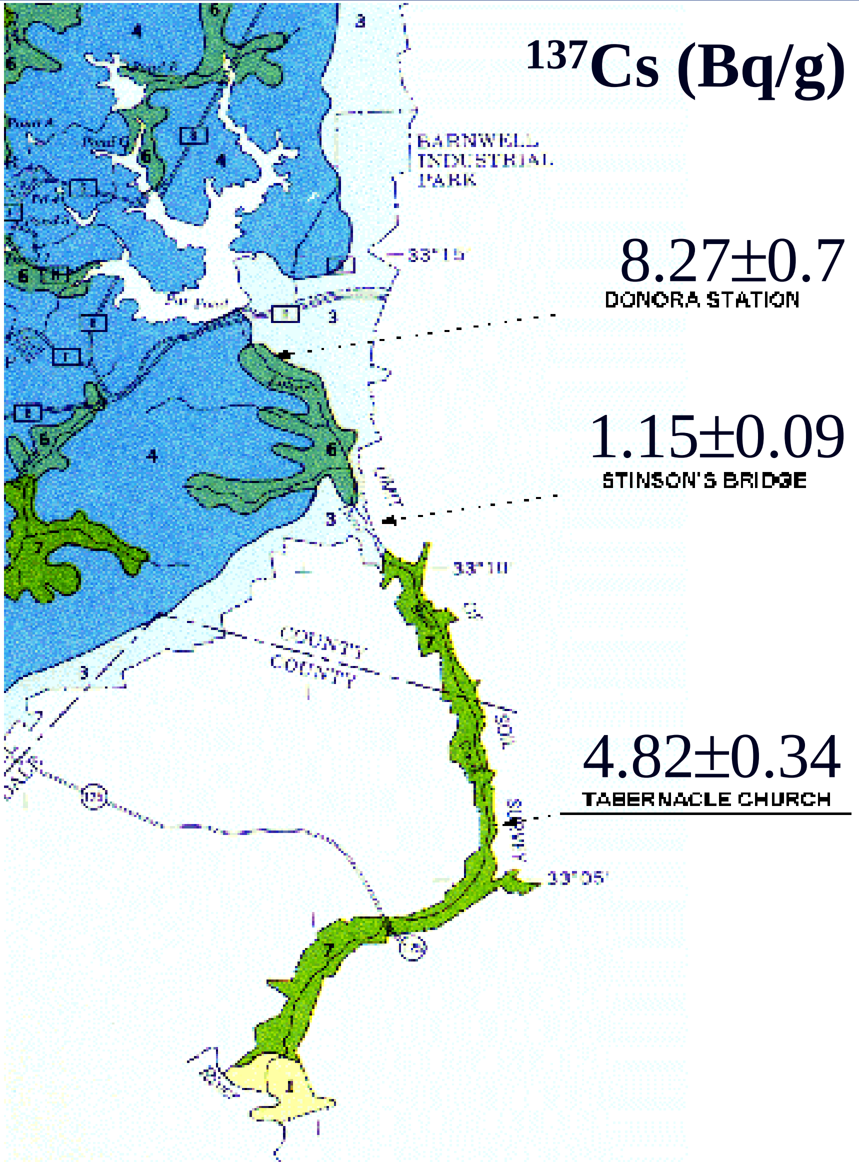
500mg soil | Saliva, gastric fluid | Saliva, gastric and intestinal fluid | filter extract

- **^{137}Cs counted directly**
- **^{90}Sr separation**
  - 50 ml aq. sample, 7ml HNO_3 and 5ml H_2O_2
  - filter sample - 0.45um prefilter and 3M Empore Sr Rad disk
- **HF extraction**
  - 30ml Teflon sample vial with tube adaptor and Teflon tubing.
  - follow EPA method 3052, in water bath.

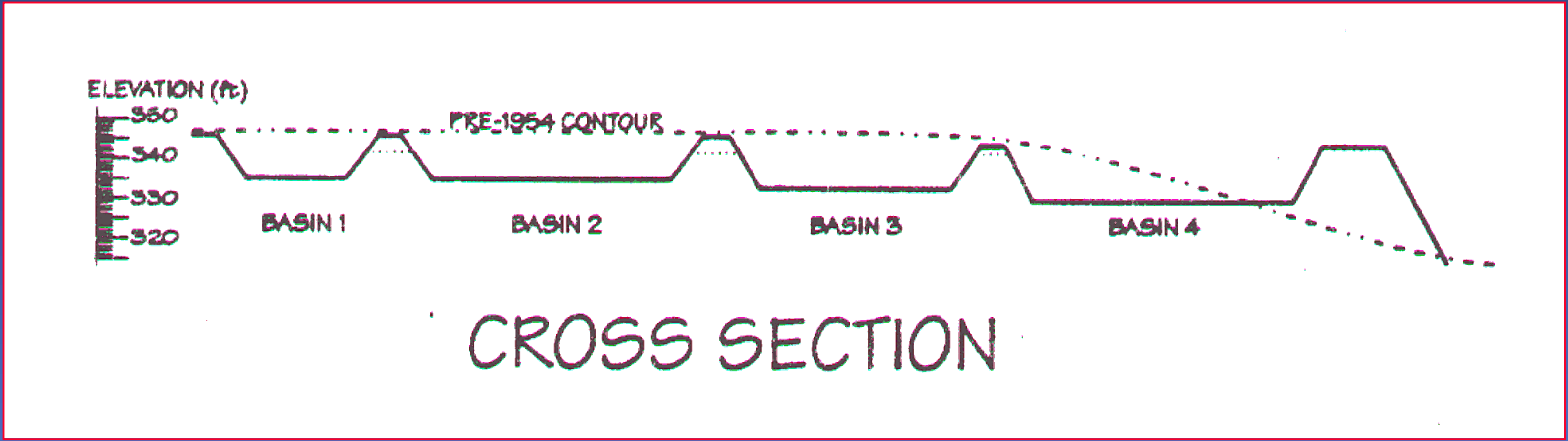
Lower Three Runs Soils

Soil	pH	% Organic Matter	Cation Exchange Capacity
TC3	5.4	13.2	42.9
SB3	6.0	6.9	19.3
DS1	5.5	8.2	26

	% sand	% silt	% clay
TC3	48	30	22
SB3	69	19	11
DS1	59	23	17

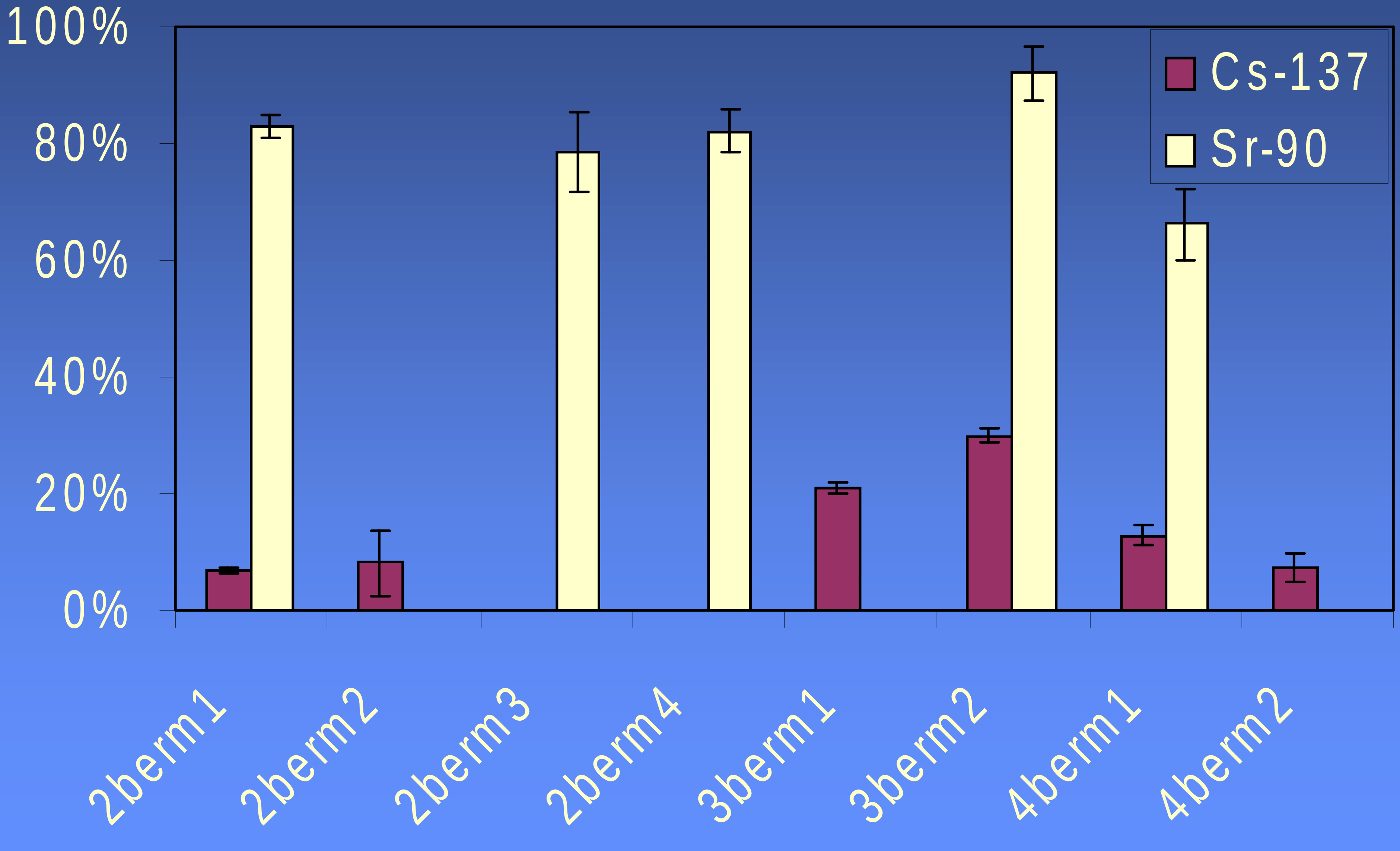


Characterization of Seepage Basin Soils

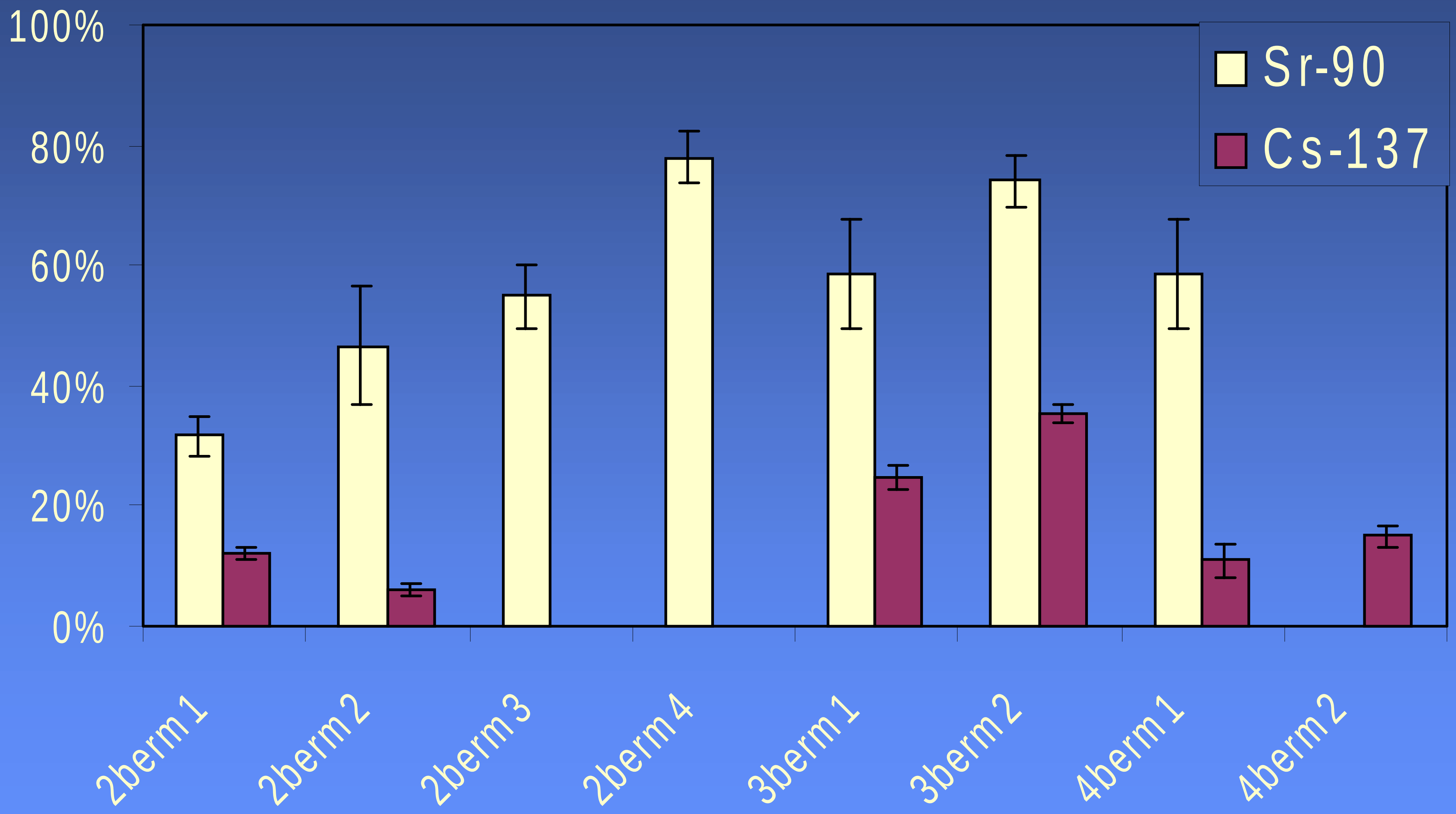


	2 berm 1	2 berm 2	2 berm 3	2 berm 4	3 berm 1	3berm2	4berm1	4berm2
Depth (ft.)	1-0.5	0.5-1	1-2	2-3	0-0.5	0.5-1	0-0.5	0.5-1
^{90}Sr (Bq/g) 1.57 – 1.96* RSD<2%	1.76 *	2.96	3.9	1.04	0.75	0.5	0.12	0.04
^{137}Cs (Bq/g) RSD<10%	6.95	0.76	0.38	0.09	6.21	5.11	0.74	1.86
pH	4.59	5.12	4.69	4.78	3.86	5.06	4.21	3.95

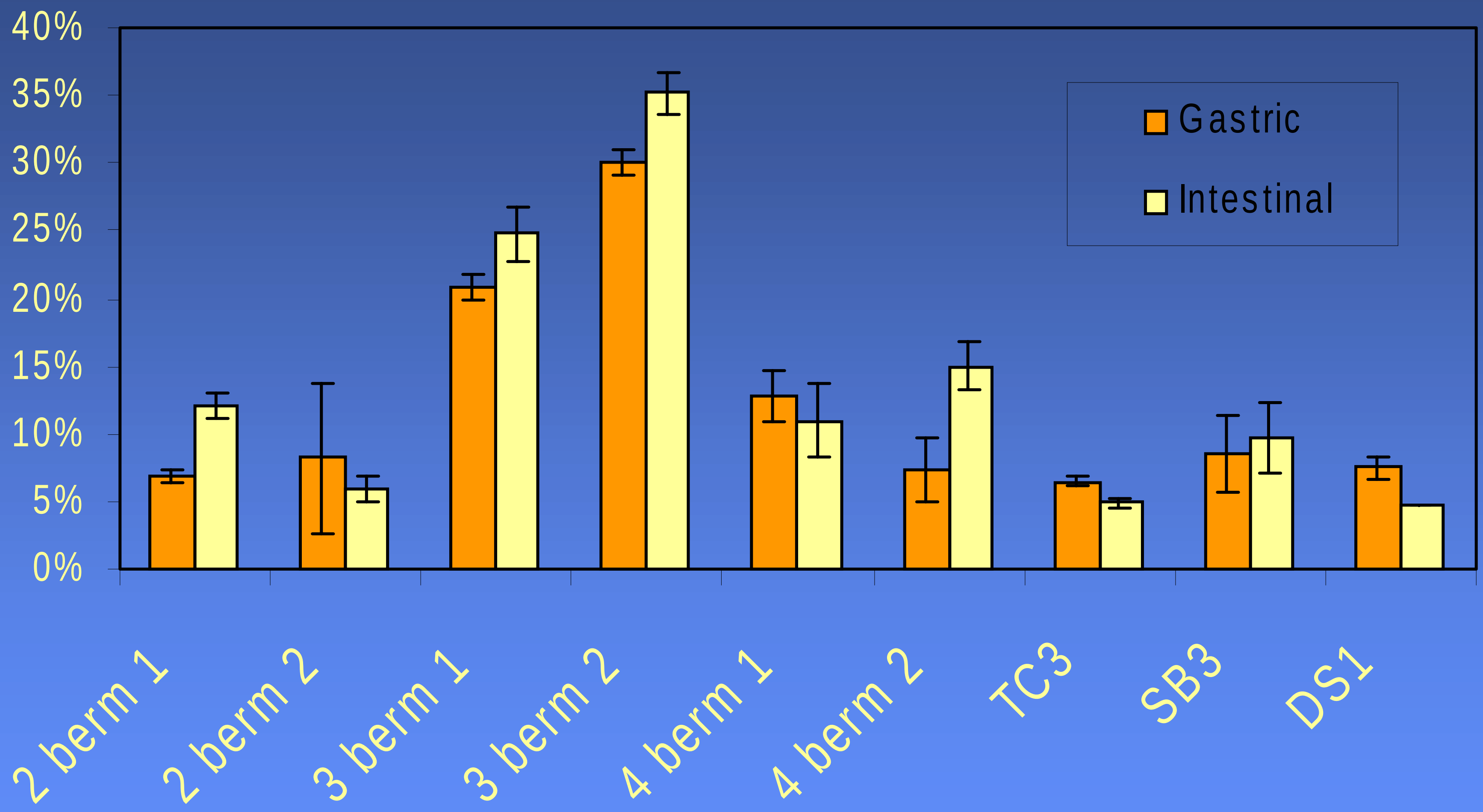
Sr-90/Cs-137 Comparison of Gastric Solubility



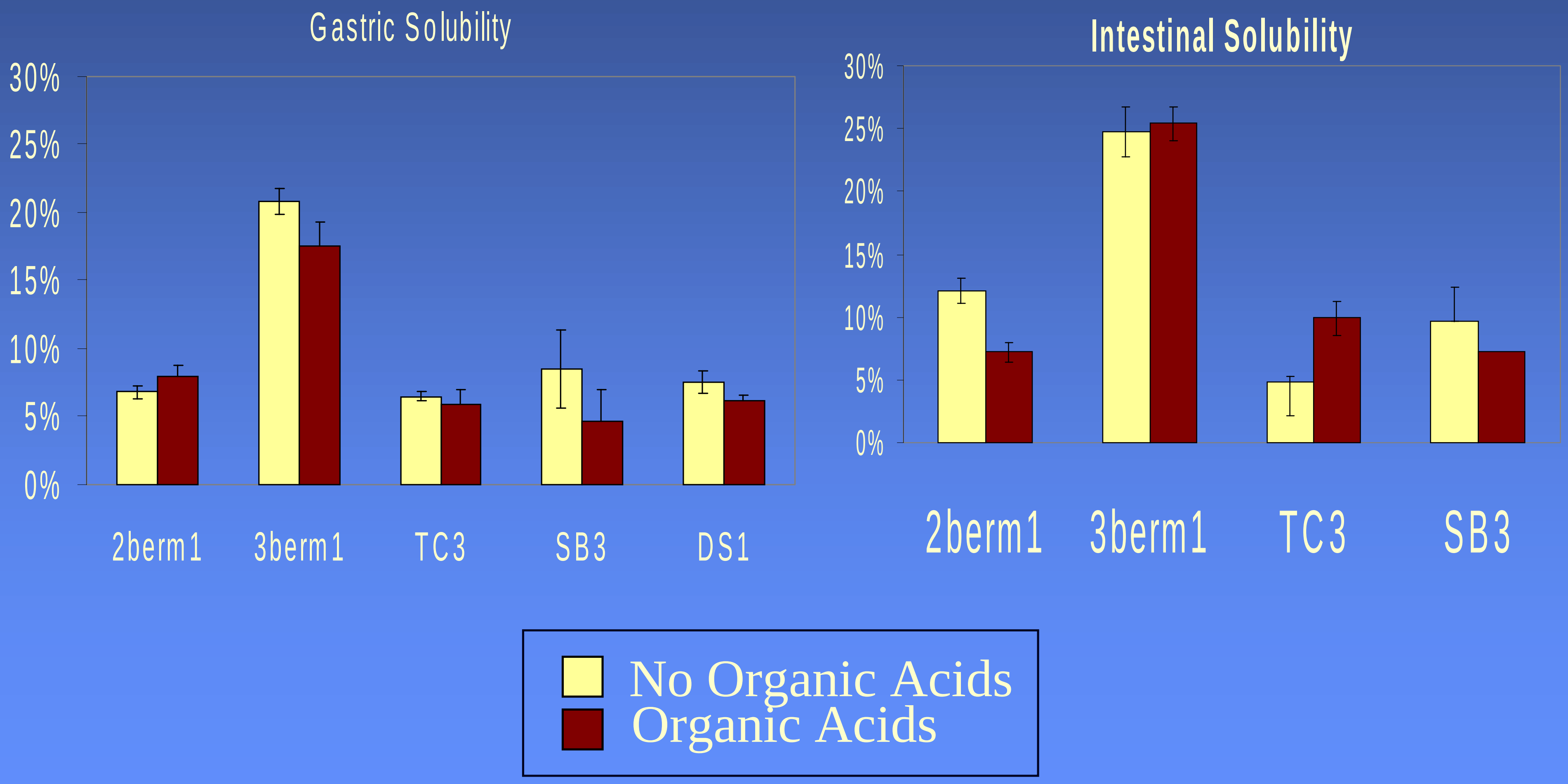
Sr-90/Cs-137 Comparison of Intestinal Solubility



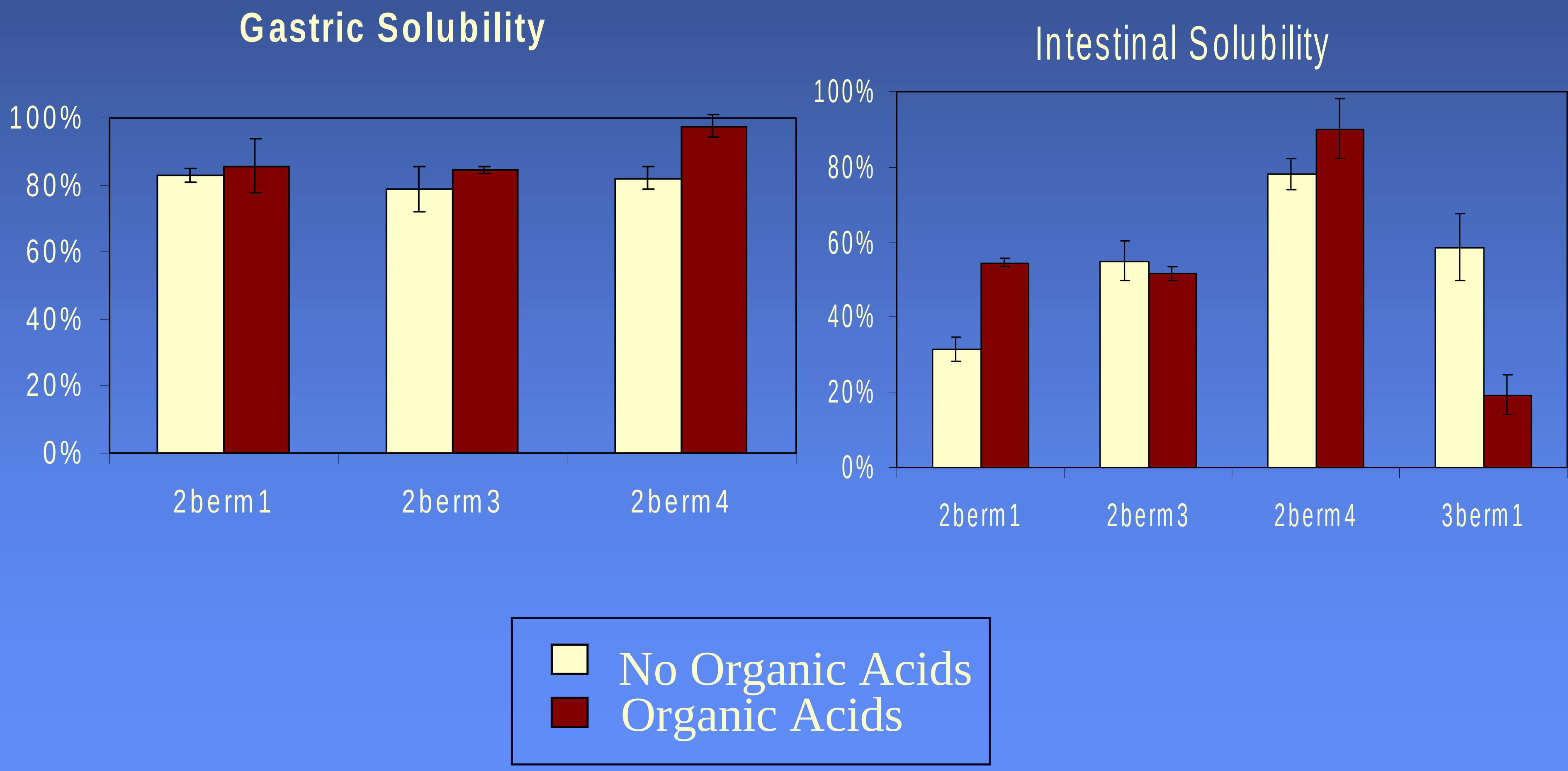
^{137}Cesium Bioaccessibility



Comparison of Cs-137 Bioaccessibility with and without Organic acids



Comparison of Sr-90 Bioaccessibility with and without Organic acids



Preliminary Results and Conclusions from ^{137}Cs and ^{90}Sr Bioaccessibility Studies

- No relationship between total and bioaccessible ^{137}Cs ($r^2 = 0.03$)
- No differences between bioaccessibility of ^{137}Cs or ^{90}Sr from gastric fluid with and without organic acids
- ^{90}Sr is more bioaccessible than ^{137}Cs in these soils. In agreement with mobility data for ^{137}Cs and ^{90}Sr, where ^{90}Sr can be more mobile than ^{137}Cs by orders of magnitude[1, 2].

[1]Salbu, B., et al. 1994
[2]Rigol, A., et al. 1999

Future Research

1. Isolate Ra^{228}, Ra^{226} for bioaccessibility measurement of a radionuclide that may be native in the soil.

2. Run statistical analyses to identify possible correlations between soil physico-chemical soil characteristics, and bioaccessibility.

3. Include bioaccessibility results in the ICRP gastrointestinal dose model and compare to background radiation dose.

Acknowledgements

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