Vol.5 (4)

PRESENTATION TO

WORKING GROUP ON RISK ASSESSMENT ISSUES

OF

EPA SCIENCES ADVISORY BOARD

MEETING AT SAN FRANCISCO, CA
JUNE 24, 1983

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SCIENCE APPLICATIONS, INC.

DISCUSSION WILL FOCUS ON:

- LEVEL OF PROTECTION

- RISK (DOSE) LIMITATION OBJECTIVES
  (INDIVIDUAL VS. POPULATION EFFECTS)

- PROBABILISTIC NATURE OF STANDARDS
  (RISK MODELING AND UNCERTAINTY)

- RATIONALE RELATED TO 10,000 YEARS CUTOFF
  (10^4 YR PERIOD OF CONCERN)

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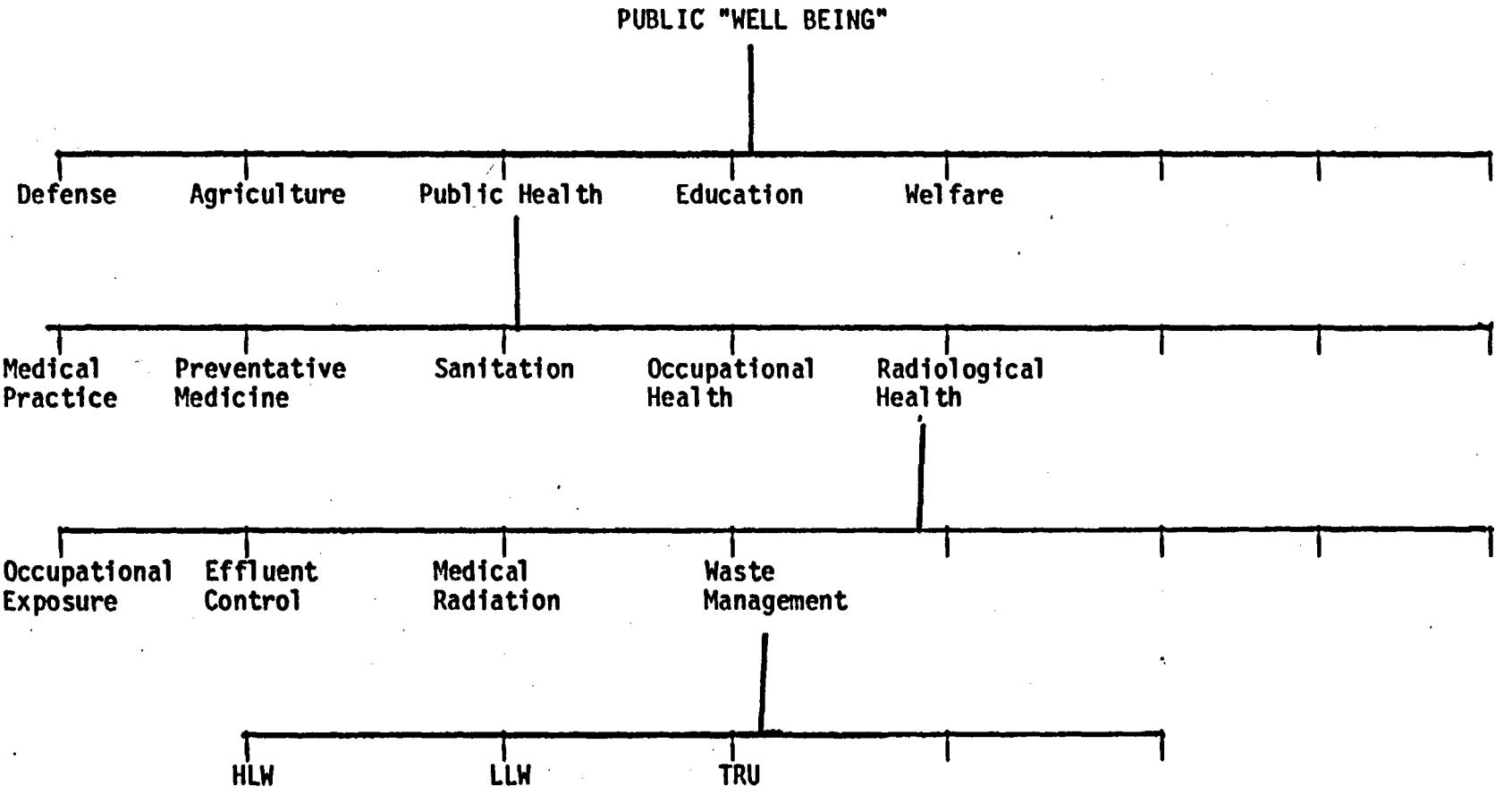
OBJECTIVE: TO IDENTIFY AND CLARIFY ISSUES

LEVEL OF PROTECTION

Is 1,000 health effects over a 10,000 year period an appropriate measure for acceptable risk?

- How does it compare with other potential hazards?
- How are health effects predicted? How conservative should such predictions be?
- Are ore body comparisons appropriate?
- Acceptable risk should be viewed within the framework of a hierarchy of societal objectives.

A HIERARCHY OF SOCIETAL OBJECTIVES



Prudent practice suggests keeping an eye on the "big picture". However, current government policies require a specialization and fragmentation of effort, thereby preventing general perspective at administrative levels below congress itself.

ESTIMATED HEALTH EFFECTS IN 1974
ASSOCIATED WITH ELECTRIC POWER PRODUCTION

Fuel	GWe • Hr	Estimated Deaths	Estimated Disabilities
Coal	830	2,000-20,000	10,000-40,000
Oil	229	100-5,000	4,000-9,000
Gas	320	6	600
Nuclear	113	10-30	80-400
Hydro	45	---	---
Wood, Waste Geothermal	3	?	?

From CONF-750706 (1975)

100,000 MTHM in a repository could represent generation of 3×10^7 GWe • Hr. of electric power.

HEALTH EFFECTS CAN BE COMPARED TO THAT OF CHEMICAL CARCINOGENS FROM COAL FIXED FROM ELECTRIC POWER PRODUCTION

- FLY AND BOTTOM ASH FROM COAL FIRED POWER PRODUCTION CONTAINS:

  10 PPM - NICKEL
  14 PPM - ARSENIC
  1 PPM - CADMIUM

- EPA CARCINOGEN ASSESSMENT GROUP RECOMMENDS LINEAR, NO- THRESHOLD ASSUMPTION. FOR EXAMPLE A VALUE OF 1.3×10^{-3} CANCERS PER GRAM OF CADMIUM INGESTED IS SUGGESTED (ANALOGOUS TO 1.8×10^{-4} HEALTH EFFECTS/MAN-REM).

- IF ALL COAL ASH IS BURIED UNDERGROUND, B.L. COHEN (RISK ANALYSIS 1:4) CALCULATES ~40 CANCERS/GWE·YR (~10^5 HEALTH EFFECTS/3.7×10^7 GWE·HR) FROM CHEMICAL CARCINOGENS

- SOLAR ENERGY USE OF CD COULD ULTIMATELY RESULT IN 80 H.E./GWE·YR

SOME CONSIDERATIONS IN DEFINING ACCEPTABLE LEVELS OF RISK FOR HLW MANAGEMENT INCLUDE:

- COMPARISON WITH ANALOGOUS ACTIVITIES
- SETTING INDIVIDUAL DOSE STANDARDS (E.G., 10 MREM/YR AS PER WISP REPORT)
- OPTIMIZATION AND/OR COST-BENEFIT ANALYSIS
- APPLICATION OF PROBABILISTIC ANALYSIS AND CRITERIA
- DEALING WITH UNCERTAINTY AND CONSERVATISM
- APPROPRIATENESS OF ORE BODY COMPARISONS

ARE ORE BODY COMPARISONS APPROPRIATE?

- ANALOG UNDERSTANDABLE TO NON-TECHNICAL PEOPLE.

- CAN BE INTUITIVELY SATISFYING.

- MANY ASSESSMENTS INDICATE POTENTIAL HAZARD OF HLW REPOSITORY BECOME LESS THAN THAT OF EQUIVALENT URANIUM ORE BODY IN < 10,000 YEARS.

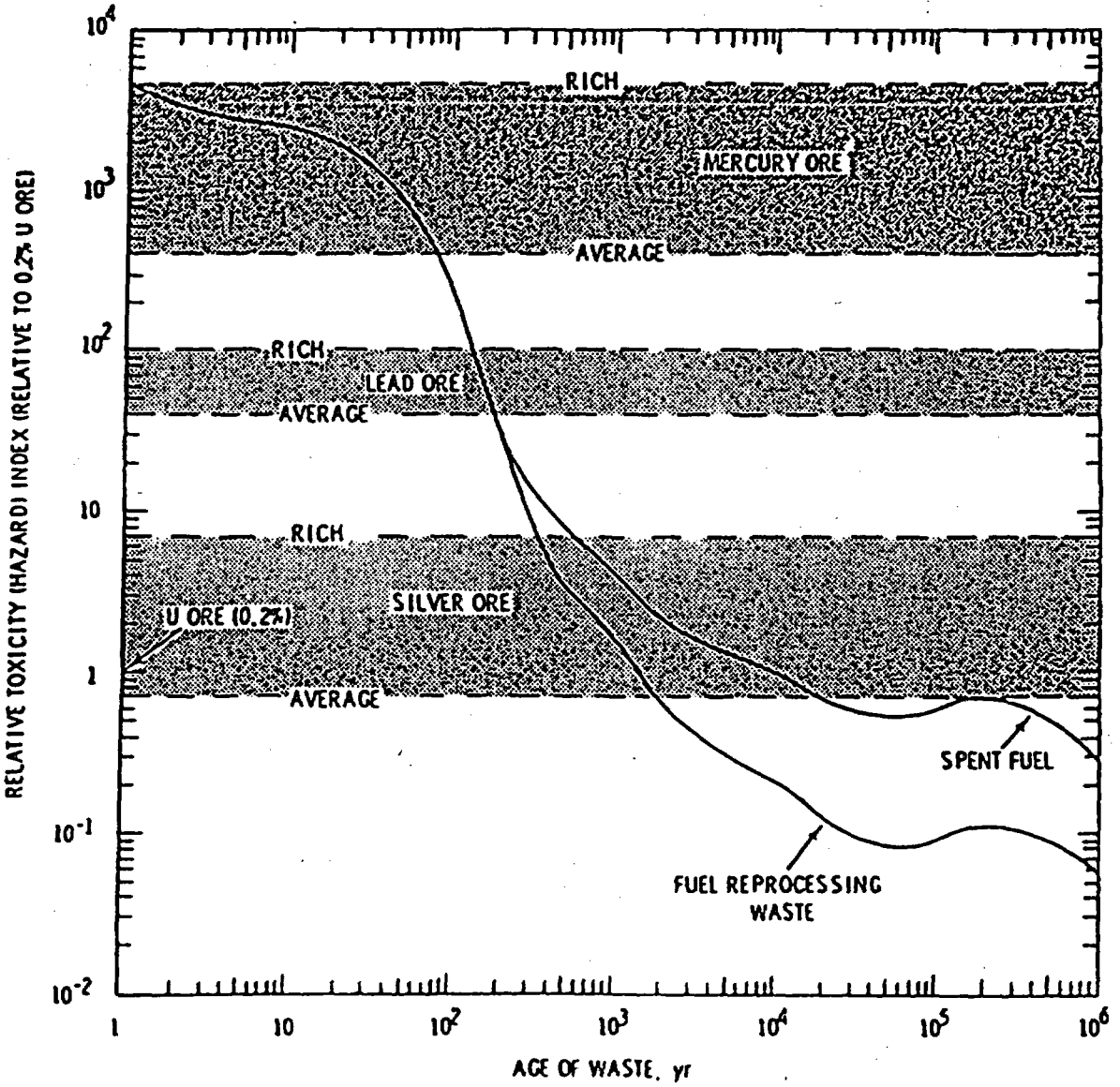
- PUBLIC EXHIBITS LITTLE CONCERN OVER ORE BODIES. WHY WORRY ABNOUT ANY LESS HAZARDOUS ENTITY.

- KRAUSHOPF COMMENT ON DRINKING WATER COMPARISON.

- APPROACH MAY EVEN BE OVER-CONSERVATIVE

  - WHERE ELSE DO WE EXHIBIT CONCERN OVER EXTRACTED TOXIC MINERALS.

From DOE/EIS-0046F



Toxicity of Spent Fuel and Reprocessing Waste from Uranium-Plutonium Recycle Relative to 0.2% Uranium Ore Necessary to Produce 1 MT of Reactor Fuel

NUCLEAR WASTE RADIOLOGICAL PROTECTION OBJECTIVES

- WHO ARE WE PROTECTING?
- HOW MUCH PROTECTION IS ENOUGH?
- INDIVIDUAL VS. POPULATION LIMITS
  - MAY, TO SOME DEGREE, CONFLICT WITH EACH OTHER (CONFINE AND CAPTURE VS. DILUTE AND DISPERSE)
  - E.G., LIMITED INDIVIDUAL EXPOSURE COULD BE ASSURED BY OCEAN DISPOSAL
  - SLOW VS. FAST AQUIFER CASE
  - INTRUDERS, AND OTHER BIZZARE SCENARIOS
  - IN GEOLOGIC DISPOSAL, DETERMINATION OF MAXIMUM INDIVIDUAL DOSE IS ARBITRARY
  - DITTO FOR POPULATION DOSE

*PREMISE THAT, DUE TO INHERENT UNCERTAINTIES, POPULATION DOSE IS EITHER MORE OR LESS DETERMINABLE THAN INDIVIDUAL DOSE IS UNSUPPORTABLE. EITHER DETERMINATION IS TENUOUS, AT BEST.

USING CALCULATIONAL MODELS, THE PREDICTION OF HLRAW REPOSITORY CONSEQUENCES (DOSE OR HEALTH EFFECTS) CAN BE LARGELY ARBITRARY.

- JUDICIOUS SELECTION OF MODELS AND INPUT VALUES CAN GIVE ALMOST ANY "DESIRED" RESULT. THIS IS TRUE FOR EITHER INDIVIDUAL OR POPULATION DOSE DETERMINATION

- ANALOG MODELS SHOULD BE SERIOUSLY CONSIDERED FOR MODEL VALIDATION

  - I-129 CASE
  - RA-226 CASE

- EVEN ASSUMING THE EPA (ADL) MODELS ARE CONCEPTUALLY AND TECHNICALLY CORRECT, THEIR PREDICTIONS ARE STILL THE RESULT OF SET OF NECESSARILY ARBITRARY ASSUMPTIONS. AS IS THE CASE WITH MOST MODEL PREDICTIONS, EPA HAS ELECTED TO APPLY CONSERVATIVE (PESSIMISTIC) ASSUMPTIONS TO THEIR CALCULATIONS. THIS PRACTICE SEEMS LAUDABLE (ERRING ON THE SAFE SIDE), BUT OVER-CONSERVATISM CAN ALSO CAUSE PROBLEMS.

- ARE EPA MODELS "REALISTIC"?

FOR EXAMPLE, EPA "CONSERVATIVE" MODEL CONCLUDES - RELEASE OF 3 CURIES OF RADIUM FROM HLW REPOSITORY WOULD CAUSE 10 HEALTH EFFECTS OVER 10,000 YEARS

- IN USA - 2.6×10^8 CI RA IN TOP 10 METERS OF SOIL (ASSUME TOP 10 METERS OF SOIL IS IN "ACCESSIBLE ENVIRONMENT")

- AS PER EPA MODEL - 8.7×10^8 HE IN 10,000 YEARS, OR 87,000 PER YEAR

- RADIUM CAUSES $\leq$ 1.0 MREM/YEAR

- 180 MREM/YEAR (BACKGROUND + MEDICAL) WOULD CAUSE 15,000,000 HEALTH EFFECTS/YEAR IN USA

- TOTAL U.S. CANCER RATE = 200,000/YEAR

$\therefore$ SOMETHING IS WRONG!

AN ORNL CODE INDICATES PEAK INDIVIDUAL DOSE FROM RELEASE OF I-129 FROM HLW REPOSITORY COULD REACH 1.0 MREM/YR.

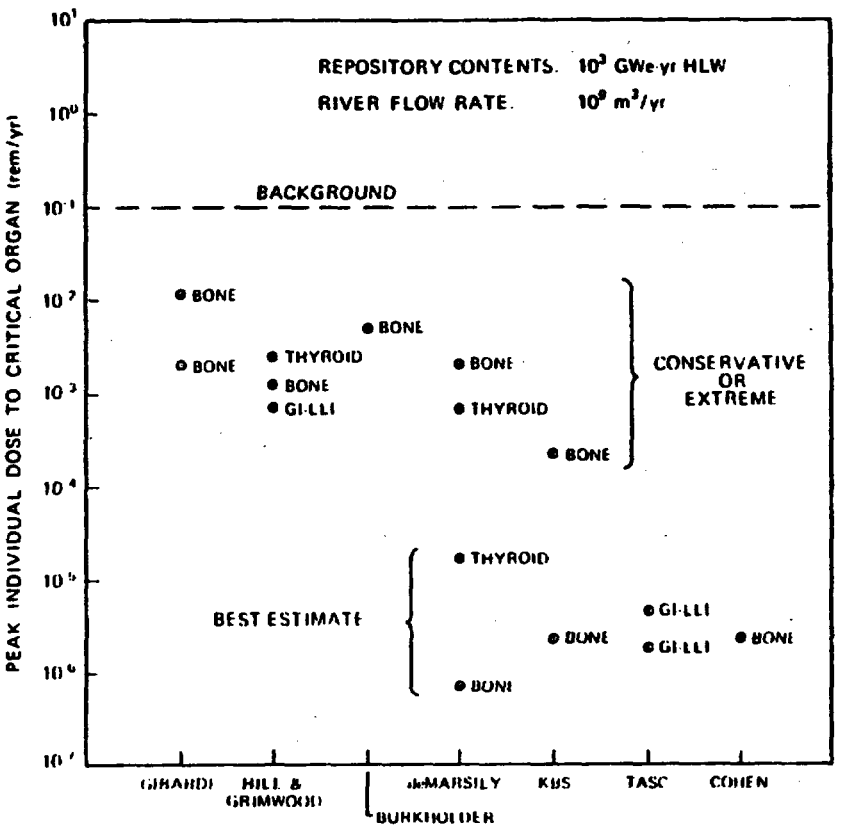
- ASSUME REPOSITORY SITED IN 10^4 KM^2 WATERSHED, AT DEPTH OF 1000 M
- 10^6 MWE-YR WASTE CONTAINS 10^7 GM I-129
- TOP KM OF WATERSHED CONTAINS 7.5×10^{12} GM I
- POPULATION AT EQUILIBRIUM WITH WATER FROM WATERSHED IN QUESTION
- I-129/TOTAL IODINE RATIO = 1.3×10^{-6}
- IF ALL IODINE IN HUMAN BODY WERE I-129, DOSE = 0.6 REM/YR
- AT EQUILIBRIUM, WORST CASE DOSE DUE TO I-129 $1.3 \times 10^{-6} \times 0.6 = 8 \times 10^{-7}$ REM/YR

* PERHAPS "BEST ESTIMATE", RATHER THAN CONSERVATIVE DOSE CALCULATIONS SHOULD BE USED, WHEN PROTECTION CRITERIA ARE ALREADY CONSERVATIVE.

COMPARISON OF CONSERVATIVE PARAMETER VALUES USED IN THE REFERENCE CASE TO MORE REALISTIC ESTIMATES

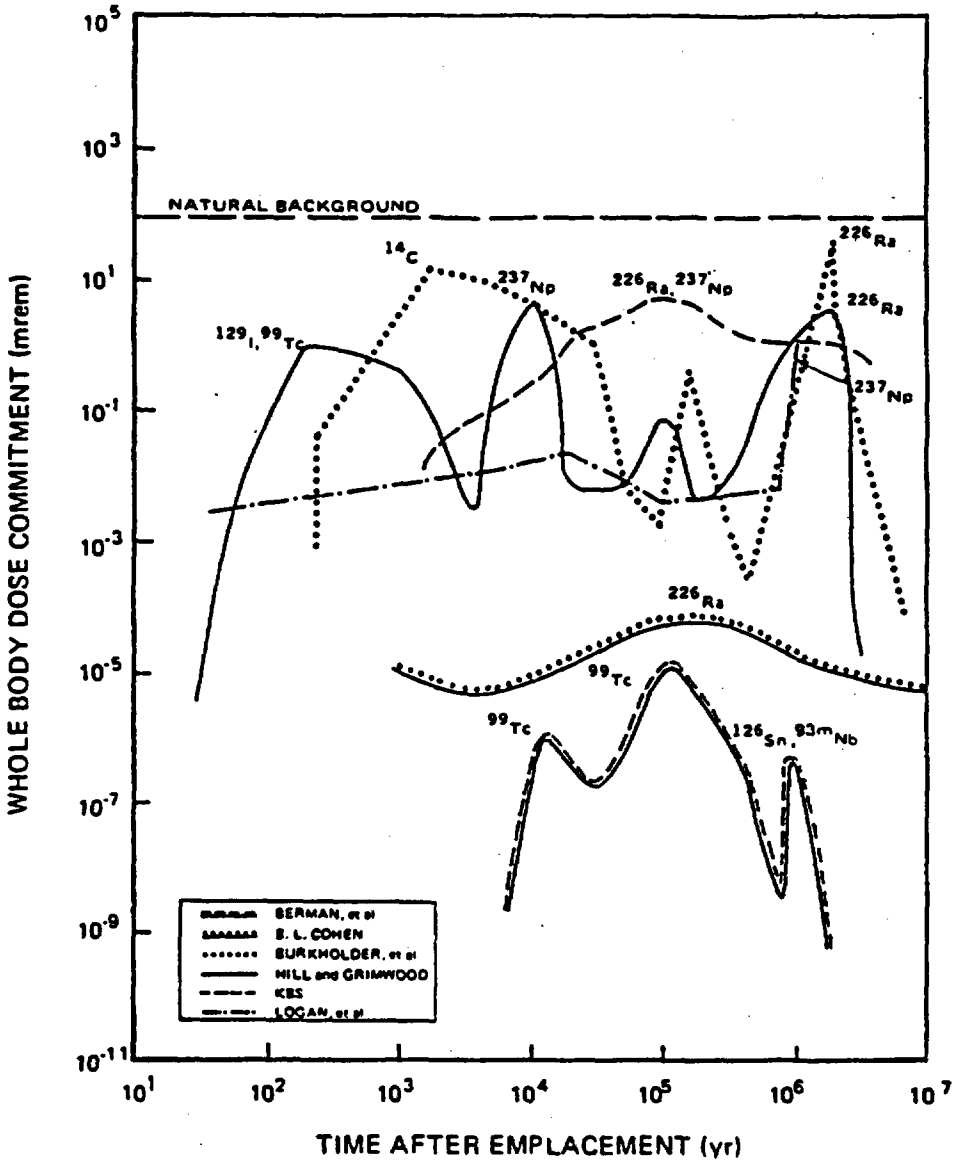
PARAMETER		CONSERVATIVE	MORE REALISTIC
Time of initial canister breach (yr)		10^3	10^3-10^4
Time for complete dissolution of the canister (yr)		5×10^3	10^4-10^5
Leach rate (1/yr)		3×10^{-5}	3×10^{-7}
Groundwater transit time (yr)		400	>3000
Retardation factors ($V_{water}/V_{nuclide}$)	I	1	1
	Tc	1	950
	Np	260	23,000
	Ra	700	48,000
	Th	5,200	46,000
	U	43	23,000
	Pu	1,100	5,700
	Am	84,000	610,000

from EPRI NP-1197



Normalized Peak Individual Doses for HLW Reference Scenarios

From EPRI NP-1197



Potential Dose to an Individual as Predicted by Six Major Risk Assessment Studies

from EPRI NP-1197

INDIVIDUAL VS. POPULATION DOSE LIMITATION NEED NOT BE AN "EITHER/OR" POLICY

- THERE IS MERIT IN LIMITING INDIVIDUAL AND POPULATION DOSE.

- IAEA, WHO, AND NUREG-0579 CALL FOR APPLICATION OF BOTH

- INDIVIDUAL DOSE LIMITS PROVIDE A CONSTRAINT (SPEED LIMIT). COLLECTIVE DOSE PROVIDES A BASIS FOR OPTIMIZATION

- SELECTION OF ONE OF SEVERAL SUCCESSFUL ALTERNATIVES (THOSE THAT MEET INDIVIDUAL DOSE CONSTRAINT) SHOULD BE BASED ON AN OPTIMIZATION PRINCIPLE (E.G., COST/BENEFIT ANALYSIS)

ON COST/BENEFIT ANALYSIS (OPTIMIZATION)

- IAEA (ICRP) Approach
- WHO Approach
- NUREG-0579 Approach

SOME CONSIDERATIONS ON THE APPLICATION OF JUSTIFICATION, OPTIMIZATION, AND/OR COST-BENEFIT PRINCIPLES INCLUDE:

- THESE PRINCIPLES ARE MOST RELEVANT TO POPULATION (COLLECTIVE) DOSE EVALUATIONS (E.G., MAN-REM OR HEALTH EFFECTS)

- APPLICATION TO INDIVIDUAL DOSE LIMITATION IS QUESTIONABLE, AT BEST, SINCE EFFECT IS CONDITIONAL ON DOSE RANGE

  - STOCHASTIC VS. NON-STOCHASTIC

  - DE-MINIMUS??

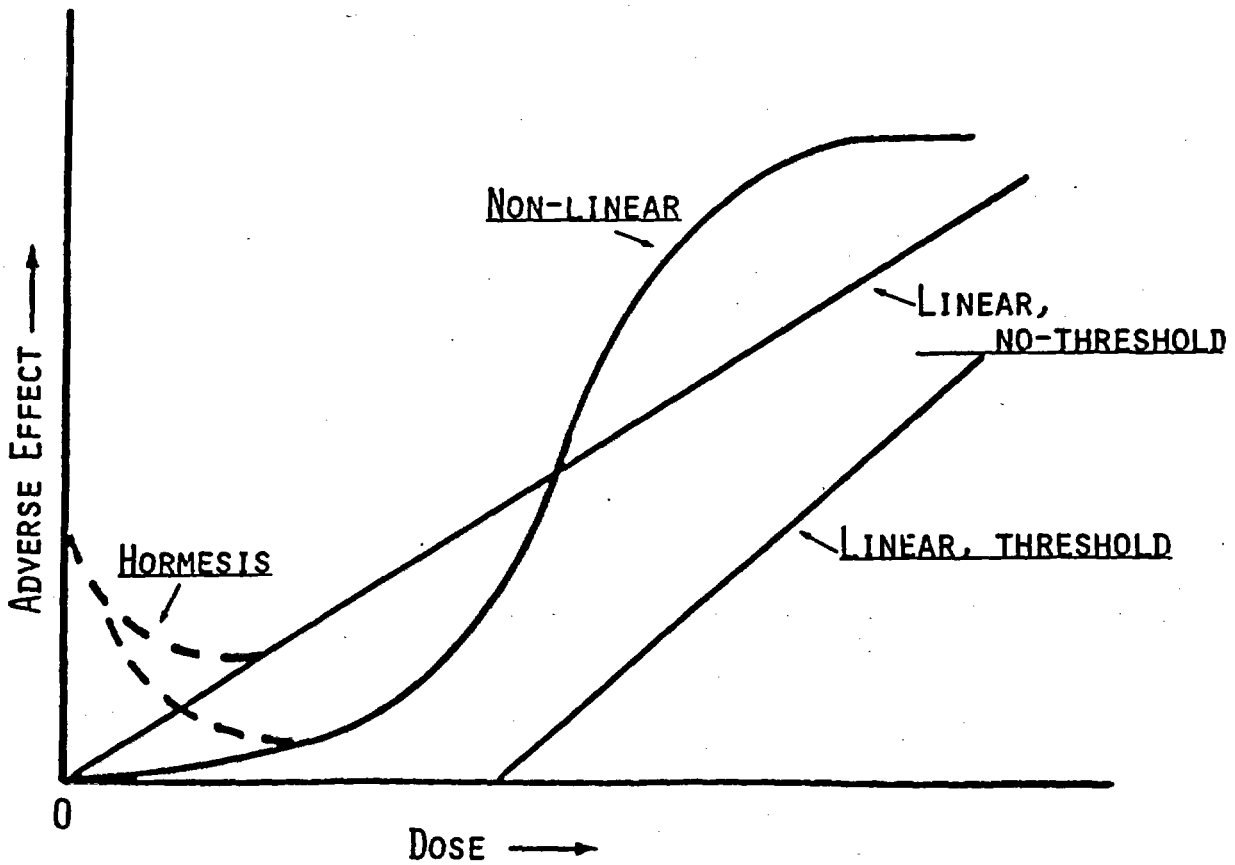
  - ENTIRELY DEPENDANT ON NATURE OF THE DOSE-RESPONSE RELATIONSHIP (SEE NEXT FIGURE)

  - VALIDITY OF POPULATION DOSE CALCULATIONS MAY ALSO BE QUESTIONABLE

- IN ANY CASE, ANALYSIS MUST BE BASED ON MARGINAL RATHER THAN ABSOLUTE VALUES

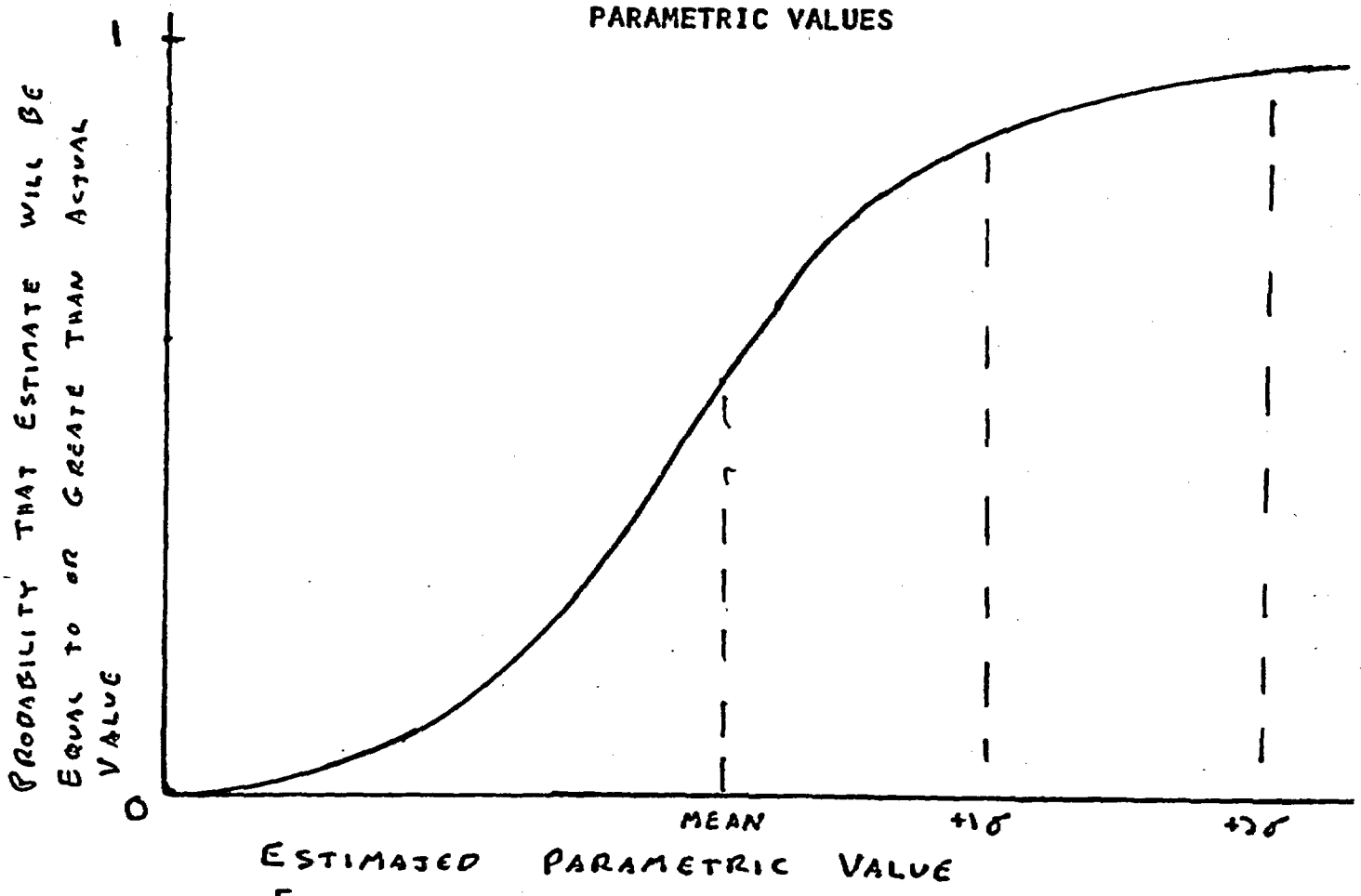
COMPARING INHERENT TOXICITY OF DIFFERENT MATERIALS CAN BE HIGHLY SPECULATIVE:

- STOCHASTIC VS. NON-STOCHASTIC EFFECTS
- THRESHOLD VS. NON-THRESHOLD EFFECTS
- LINEAR VS. NON-LINEAR EFFECTS
- HORMESIS

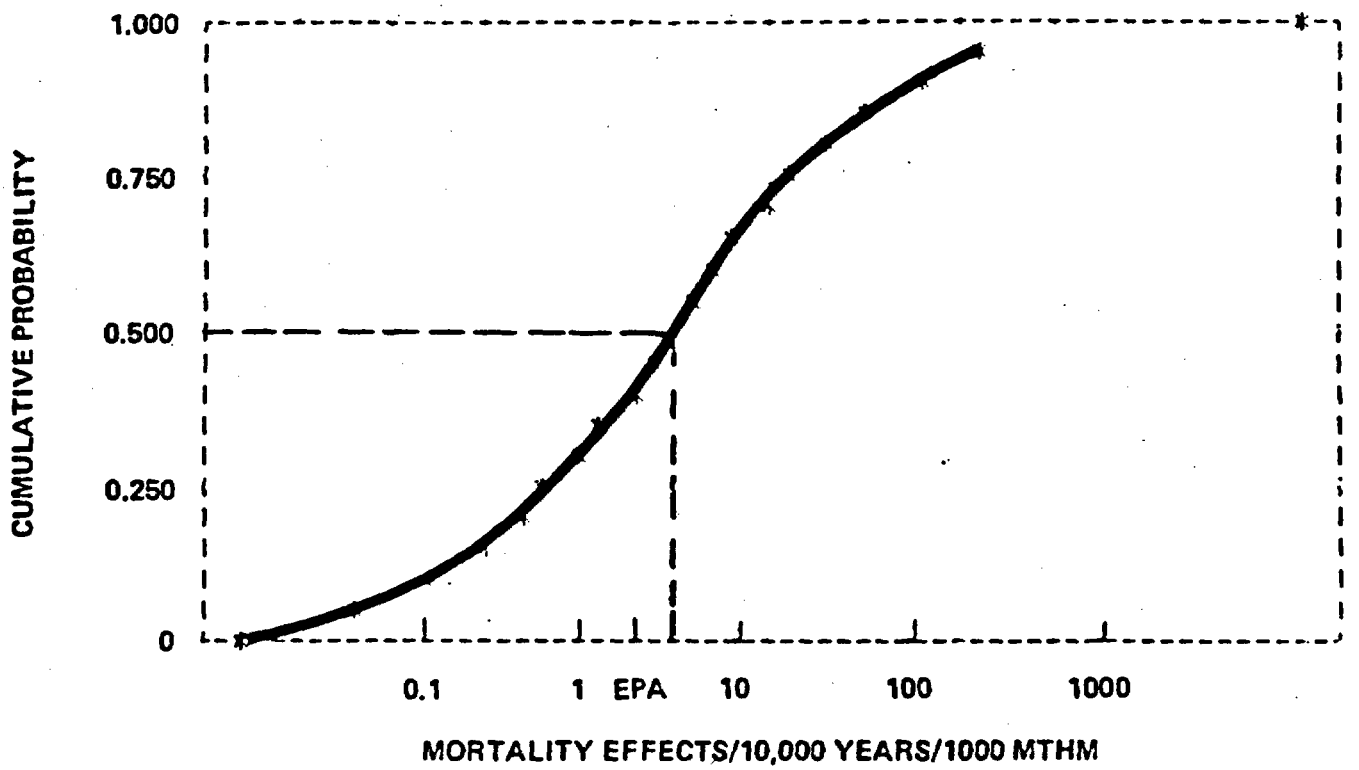


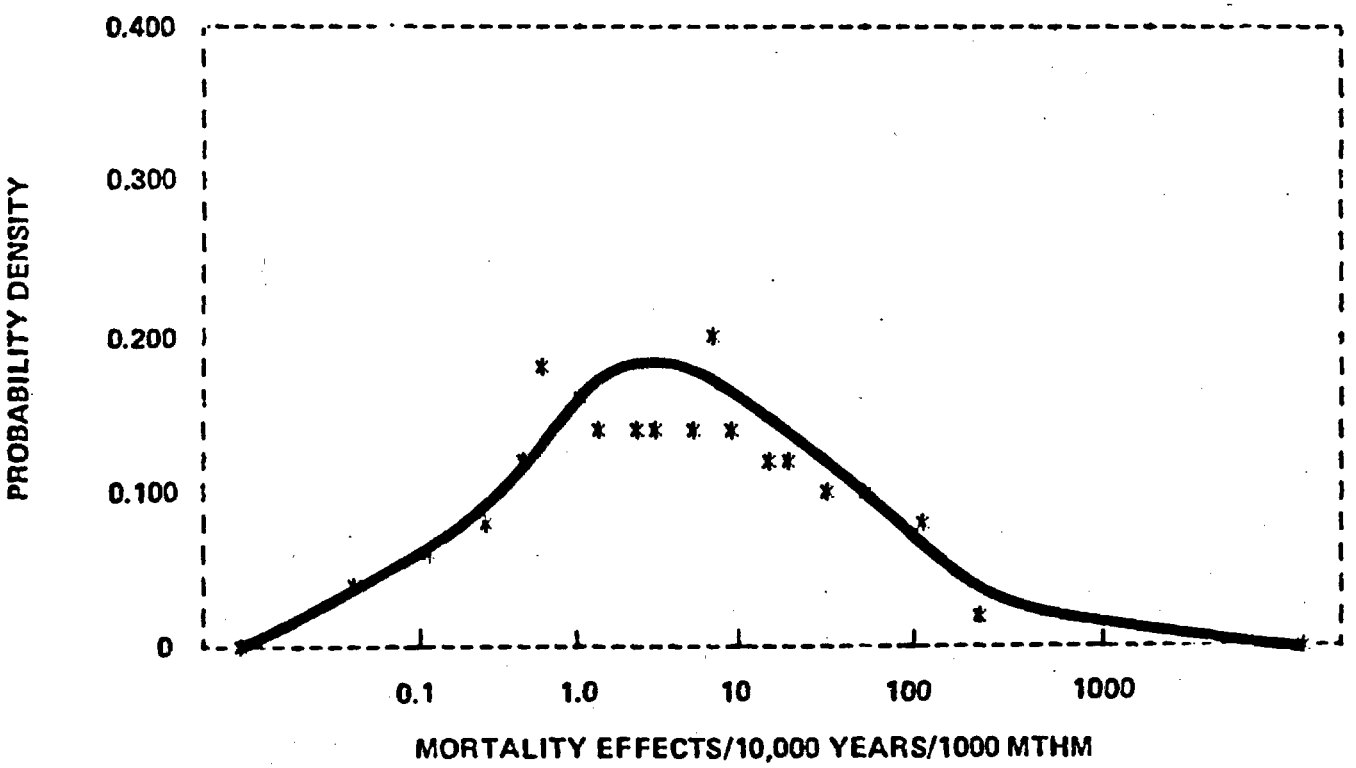
ON UNCERTAINTY AND CONSERVATISM

- HOW CONSERVATIVE DO WE NEED TO BE?
- HOW CERTAIN DO WE NEED TO BE?
- CALCULATIONAL MODELS INCORPORATE MANY ESTIMATED PARAMETRIC VALUES



- FROM THE RANGE OF POSSIBLE VALUES, WHERE IS IT PRUDENT TO SELECT INPUT PARAMETERS? MEAN? $+1\sigma$? $+2\sigma$?
- EFFECT OF COMPOUNDING IMPROBABLE VALUES
- ENVIROSPHERE REPORT





PROBABILITY DISTRIBUTIONS SHOWING UNCERTAINTY ABOUT MORTALITY EFFECT ESTIMATES FOR Ra-226 RELEASES FROM A URANIUM ORE BODY EQUIVALENT TO A 1000 MTHM REPOSITORY

Influence of Uncertainty on Radionuclide Release Limits
(Releases in Curies/1000 MTHM,
Risk Limit = 10 Effects/10,000 Years/1000 MTHM)

Nuclide	40 CFR 191 Release Limits	From Median or Best Estimate	From Extremes of 90% Confidence Interval
AM-241	10	2,000	50 - 40,000
AM-243	4	2,000	57 - 53,000
CS-135	2,000	20,000	800 - (undefined)
CS-137	500	8,300	830 - (undefined)
NP-237	20	21	1 - 500
PU-238	400	10,000	44 - 1,600,000
PU-239	100	1,000	0.3 - 400,000
PU-240	100	1,000	0.9 - 400,000
PU-242	100	260	0.25 - 290,000
RA-226	3	180	4.3 - 3,000
SR-90	80	5,700	200 - (undefined)
TC-99	10,000	330,000	8,300 - 10,000,000
SN-126	80	1,600	40 - (undefined)

IF 10,000 YEAR CUTOFF CAUSES EXCESSIVE PROBLEMS, A POSSIBLE SOLUTION IS:

- SET HEALTH EFFECTS RATE (I.E. X NUMBER OF HEALTH EFFECTS IN ANY 10,000 YEAR INCREMENT OF TIME PAST CLOSURE)

- SOME OTHER TIME PERIOD FOR INTEGRATION OF EFFECTS MIGHT BE EVEN BETTER SUITED (100?, 1000?, 1 MILLION?)

SHOULD FUTURE EFFECTS BE DISCOUNTED?

- IF ANSWER IS <u>YES</u>, HLW MANAGEMENT BECOMES ESSENTIALLY A NON-PROBLEM.

- IF ANSWER IS <u>NO</u>, WHY NOT? SHOULD SIMILAR RATIONALE BE APPLIED GENERALLY? IF THIS WERE THE CASE, THERE COULD BE PROFOUND CONSEQUENCES.

SUMMARY OF ISSUES AND RECOMMENDATIONS

LEVEL OF PROTECTION

ISSUES:

- THE APPROPRIATENESS OF 1,000 HE/10,000 YEARS AS A MEASURE OF ACCEPTABLE RISK.
- THE VALIDITY OF THE 1,000 HE VALUE, GIVEN THE INHERENT CONSERVATISMS OF THE MODELS AND DATA
- THE VALIDITY OF THE 1,000 HE VALUE BASED ON THE EXTRAPOLATION OF THE BEIR DATA WELL BEYOND ITS AREA OF VALIDITY; THE USE OF THE LINEAR DOSE-RESPONSE MODEL
- THE APPROPRIATENESS OF BASING THE VALUE ON ORE BODY COMPARISONS.

SUGGESTIONS:

- INCREASE UNDERLYING STANDARD BY AT LEAST A FACTOR OF 10 BASED ON (1) ORE BODY COMPARISON, (2) OTHER RISK VALUES IN RADIATION PROTECTION.
- UTILIZE BEST ESTIMATE RATHER THAN CONSERVATIVE MODELS AND DATA WHERE AVAILABLE.
- TO AVOID MISAPPLICATION IN LICENSING, NOT INCLUDE REFERENCE TO ALARA SINCE THE STANDARD ALREADY SPECIFIES LEVELS OF ACCEPTABLE RISK.

INDIVIDUAL VERSUS POPULATION CRITERIA

ISSUES:

- APPROPRIATENESS OF THE EPA USE OF LONG-TERM POPULATION ASSUMPTIONS.
- THE ABILITY OF A POPULATION STANDARD TO PROTECT SIGNIFICANT GROUPS OF INDIVIDUALS.
- MEANINGFULNESS OF EVEN CONSIDERING INTRUSION.

SUGGESTIONS:

- RETAIN POPULATION DOSE STANDARD BASED ON ITS ESSENTIAL EQUIVALENCE TO A 10 MR INDIVIDUAL ANNUAL DOSE LIMIT.
- CONSOLIDATE SCENARIOS RESULTING IN LARGE INDIVIDUAL DOSES WITH OVERALL POPULATION EFFECTS. DISREGARD THEM IF THEY DO NOT CONSTITUTE MORE THAN A SMALL PERCENT OF THE TOTAL.

THE PROBABILISTIC NATURE OF THE EXISTING PROPOSED STANDARD

ISSUES:

- IS THE SIMPLIFIED (TWO STAGES - REASONABLY FORESEEABLE VS. VERY UNLIKELY RELEASE) PROBABILISTIC APPROACH ADEQUATE?
- IS IT TOO SIMPLE TO INCORPORATE A REASONABLE SPECTRUM OF RELEASE EVENTS?
- IS IT TOO COMPLEX FROM THE STANDPOINT THAT MANY FUTURE RELEASE EVENT PROBABILITIES ARE DIFFICULT IF NOT IMPOSSIBLE TO QUANTIFY IN A MEANINGFUL WAY.
- DOES THE APPROACH PROVIDE TOO MUCH OF A POTENTIAL FOR LICENSING CONTENTION BECAUSE OF THE UNCERTAINTIES OF FORECASTING FUTURE EVENTS.

SUGGESTIONS:

- UTILIZE A SINGLE ASSURANCE LEVEL (BASED ON 10,000 YEARS) WITH RELEASE LIMITS INCREASED AS IN THE PREVIOUS DISCUSSIONS ON LEVELS OF PROTECTION.
- SPECIFY DE MINIMUS LEVEL FOR EVENT PROBABILITIES TO BE INCLUDED IN ANY ANALYSIS TO DEMONSTRATE COMPLIANCE.