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FERNALD ENVIRONMENTAL MANAGEMENT PROJECT RISK ROUNDTABLE - MARCH 23, 1993

03/23/93

DOE-FN PUBLIC
75
OVERHEADS

Fernald Environmental Management Project

Risk Roundtable

March 23, 1993

GLOSSARY

RISK ASSESSMENT

ABSORBED DOSE

The amount of a substance penetrating the exchange boundaries of an organism after contact. Absorbed dose is calculated from the intake and the absorption efficiency. It usually is expressed as mass of a substance absorbed into the body per unit body weight per unit time (e.g., mg/kg-day).

ADMINISTERED DOSE

The mass of a substance given to an organism and in contact with an exchange boundary (e.g., gastrointestinal tract) per unit body weight per unit time (e.g., mg/kg-day).

ANALYTES

The chemicals for which a sample is analyzed.

APPLIED DOSE

The amount of a substance given to an organism, especially through dermal contact.

CHEMICALS OF POTENTIAL CONCERN

Chemicals that are potentially site-related and whose data are of sufficient quality for use in the quantitative risk assessment.

CHRONIC DAILY INTAKE (CDI)

Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a long period of time (as a Superfund program guideline, seven years to a lifetime).

CONTACT RATE

Amount of medium (e.g., ground water, soil) contacted per unit time or event (e.g., liters of water ingested per day).

DOSE-RESPONSE EVALUATION

The process of quantitatively evaluating toxicity information and characterizing the relationship between the dose of a contaminant administered or received and the incidence of adverse health effects in the exposed population. From the quantitative dose-response relationship, toxicity values are derived that are used in the risk characterization step to estimate the likelihood of adverse effects occurring in humans at different exposure levels.

RISK ASSESSMENT
(Continued)

EXPOSURE

Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.g., skin, lungs, gut) and available for absorption.

EXPOSURE ASSESSMENT

The determination or estimation (qualitative or quantitative) of the magnitude, frequency, duration, and route of exposure.

EXPOSURE PATHWAY

The course a chemical or physical agent takes from a source to an exposed organism. An exposure pathway describes a unique mechanism by which an individual or population is exposed to chemicals or physical agents at or originating from a site. Each exposure pathway includes a source or release from a source, an exposure point,a nd an exposure route. If the exposure point differs from the source, a transport/exposure medium (e.g., air) or media (in cases of intermedia transfer) also is included.

EXPOSURE POINT

A location of potential contact between an organism and a chemical or physical agent.

EXPOSURE ROUTE

The way a chemical or physical agent comes in contact with an organism (e.g., by ingestion, inhalation, dermal contact).
EXPOSURE

Contact of an organism with a chemical or physical agent. Exposure is quantified as the amount of the agent available at the exchange boundaries of the organism (e.r., skin, lungs, gut) and available for absorption.

HAZARD IDENTIFICATION

The process of determining whether exposure to an agent can cause an increase in the incidence of a particular adverse health effect (e.g., cancer, birth defect) and whether the adverse health effect is likely to occur in humans.

000003

GLOSSARY

RISK ASSESSMENT
(Continued)

INTAKE

A measure of exposure expressed as the mass of a substance in contact with the exchange boundary per unit body weight per unit time (e.g., mg chemical/kg-day). Also termed the normalized exposure rate equivalent to administered dose.

LIFETIME AVERAGE DAILY INTAKE

Exposure expressed as mass of a substance contacted per unit body weight per unit time, averaged over a lifetime.

QUALITY ASSURANCE PROJECT PLAN (QAPjP)

Describes the policy, organization, functional activities, and quality assurance and quality control protocols necessary to achieve DQOs dictated by the intended use of the data (RI/FS guidance).

SAMPLING AND ANALYSIS PLAN (SAP)

Consists of a Quality Assurance Project Plan (QAPjP) and a Field Sampling Plan (FSP).

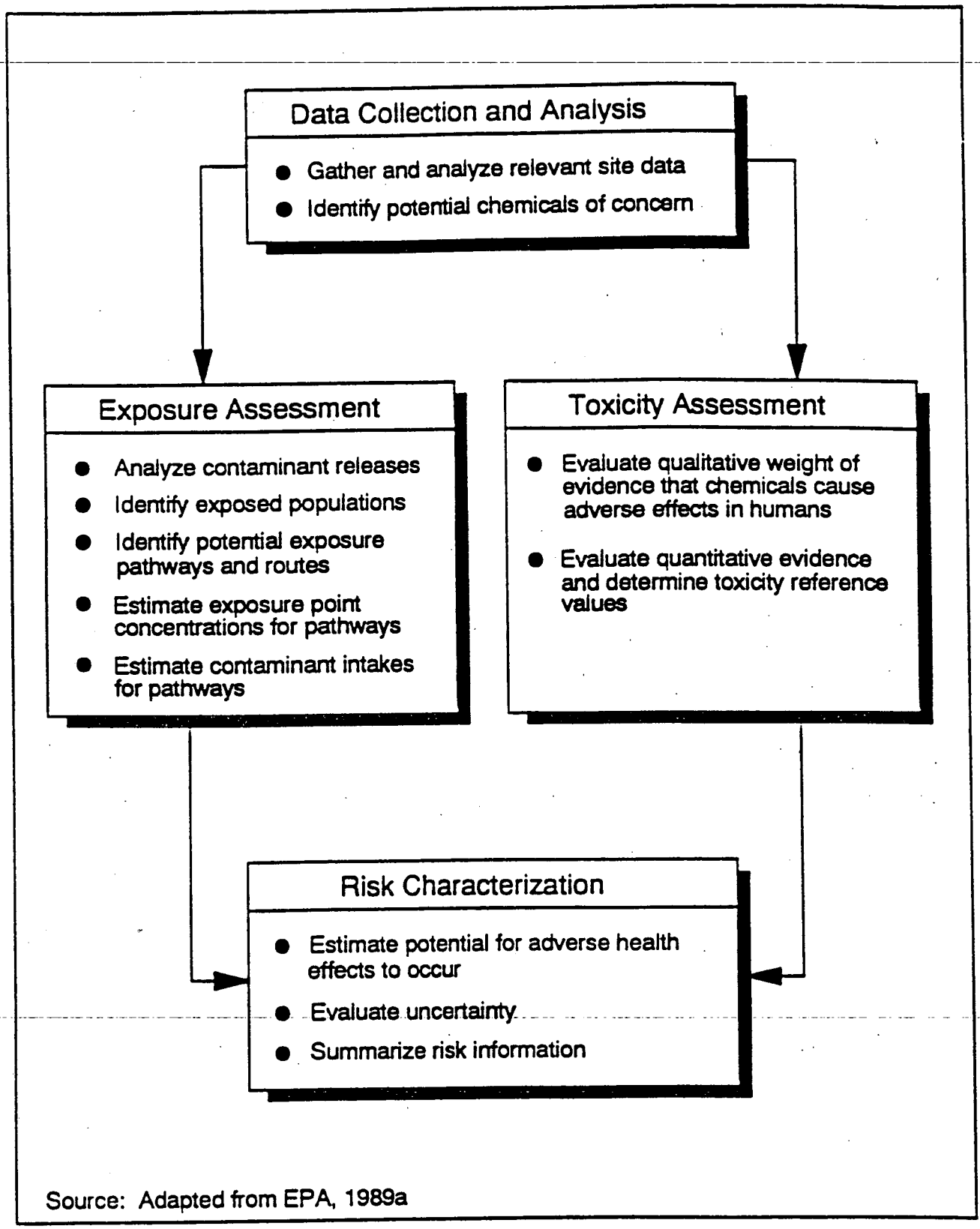
TOXICITY VALUE

A numerical expression of a substance's dose-response relationship that is used in risk assessments. The most common toxicity values used in Superfund program risk assessments are reference doses (for noncarcinogenic effects) and slope factors (for carcinogenic effects).

Chronological Schedule of Primary Reports
Required by the Amended Consent Agreement
Operable Units 1 - 5

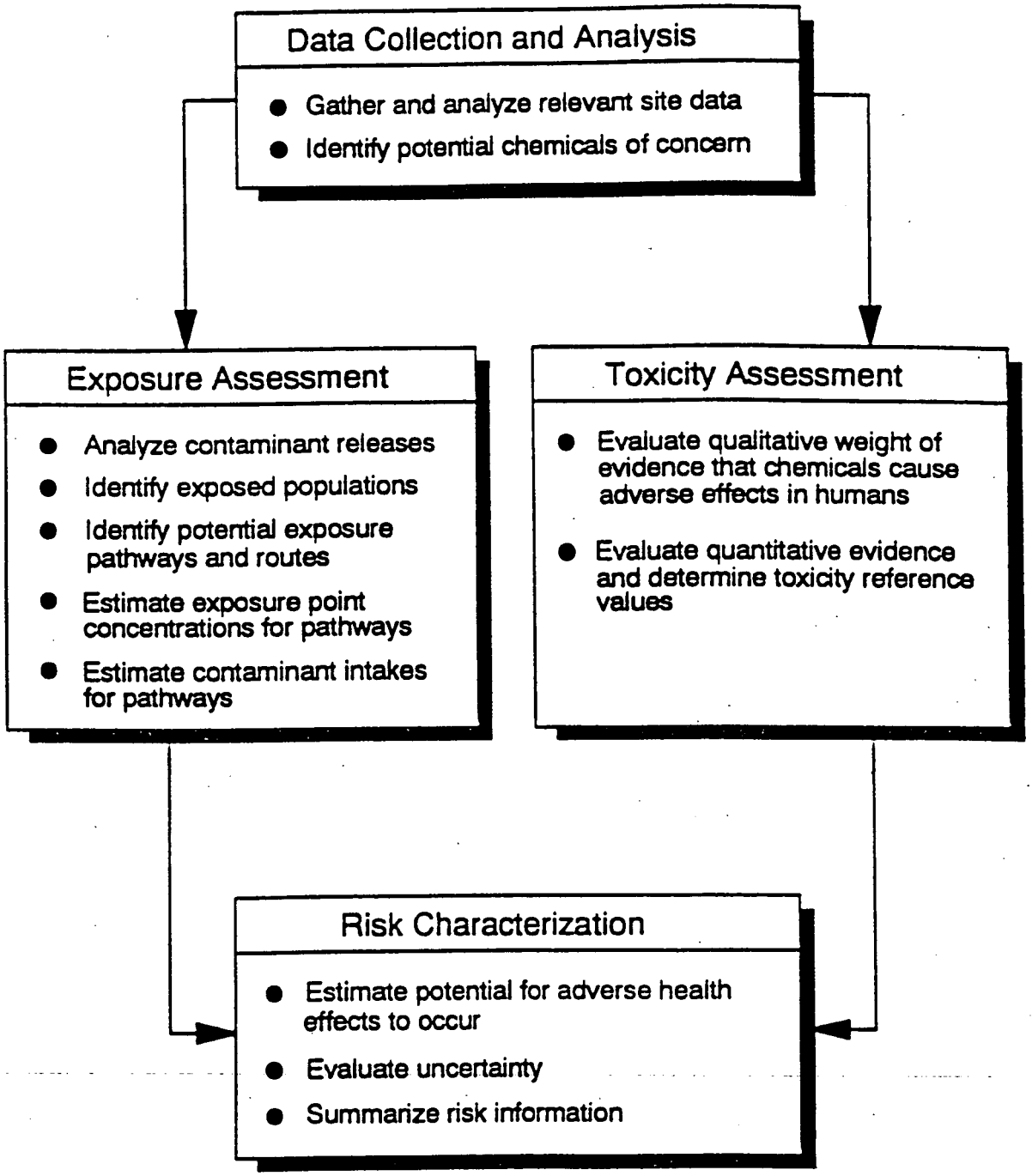
October 24, 1990	OU 4 Initial Screening of Alternatives
January 4, 1991	OU 1 Initial Screening of Alternatives
April 18, 1991	OU 2 Initial Screening of Alternatives
October 19, 1992	OU 2 Remedial Investigation/Baseline Risk Assessment
March 15, 1993*	OU 2 Feasibility Study/Proposed Plan
April 16, 1993	OU 5 Initial Screening of Alternatives
April 19, 1993	OU 4 Remedial Investigation/Baseline Risk Assessment
September 10, 1993	OU 4 Feasibility Study/Proposed Plan
October 12, 1993	OU 1 Remedial Investigation/Baseline Risk Assessment
December 10, 1993*	OU 2 Record of Decision
March 7, 1994	OU 1 Feasibility Study/Proposed Plan
June 10, 1994	OU 4 Record of Decision
June 24, 1994	OU 5 Remedial Investigation/Baseline Risk Assessment
November 16, 1994	OU 5 Feasibility Study/Proposed Plan
December 6, 1994	OU 1 Record of Decision
March 28, 1995	OU 3 Initial Screening of Alternatives
August 2, 1995	OU 5 Record of Decision
March 13, 1996	OU 3 Remedial Investigation/Baseline Risk Assessment
August 7, 1996	OU 3 Feasibility Study/Proposed Plan
May 2, 1997	OU 3 Record of Decision

* These deadlines are being negotiated with the U.S. EPA



Source: Adapted from EPA, 1989a

FIGURE 2-1
BASELINE RISK ASSESSMENT PROCESS



Source: Adapted from EPA, 1989a

FIGURE 2-1
BASELINE RISK ASSESSMENT PROCESS

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Operable Unit Specific - Risk Assessment

BRA

- characterize the sources
- determine the contaminants of concern
- identify the significant exposure pathways
- assess contaminant transport over the next 1000 years
- quantify significant exposures attributable to the OU
- select the RME scenario for the OU

FS Risk Assessment

- calculate and present estimated short and long-term risks associated with each RAA
- provide input into the FS Comprehensive Response Action Risk Evaluation
- summarize the results of the above tasks and document both the methodology and data sources used to perform them

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PROGRAMMATIC APPROACH

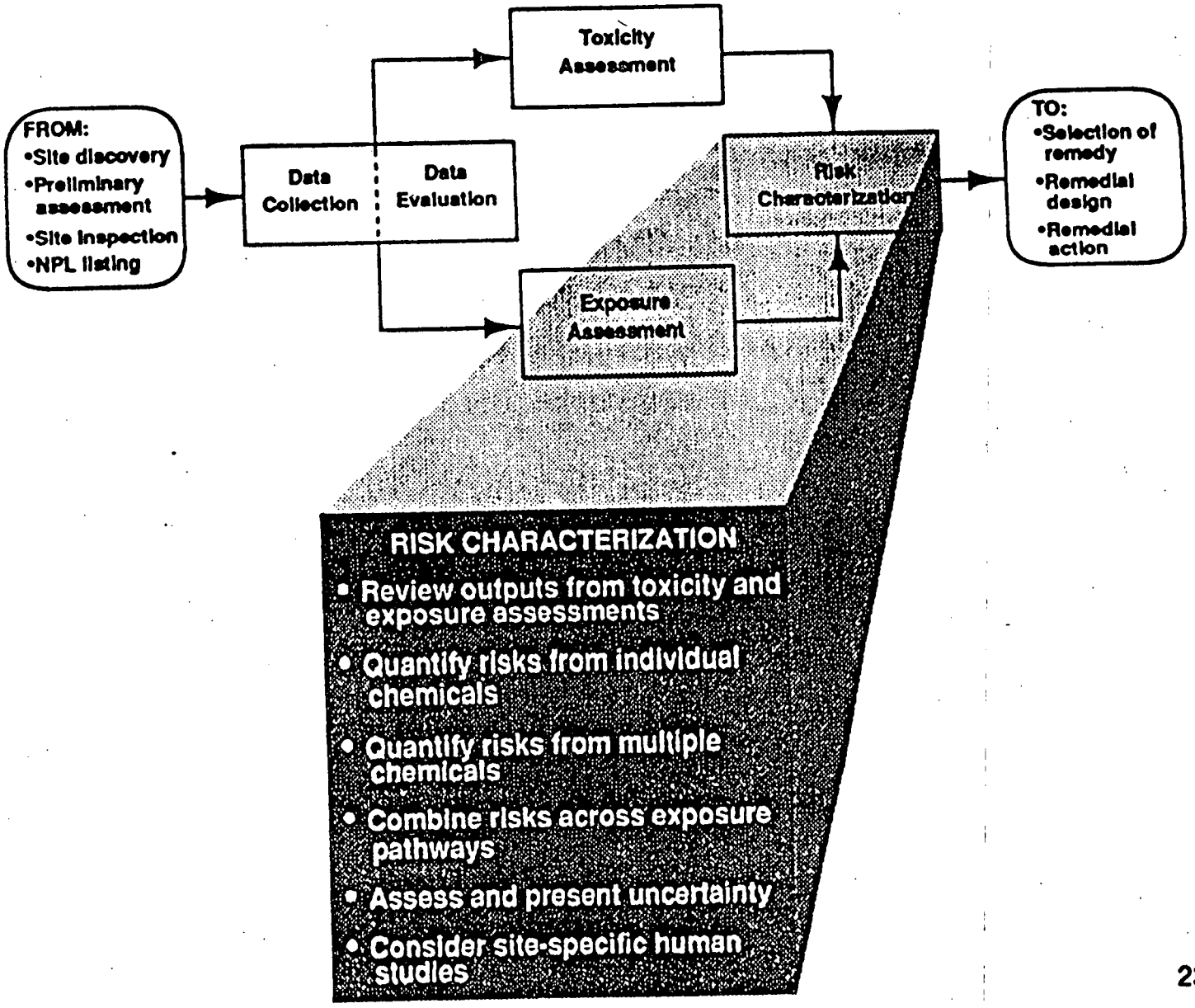
Objectives of Risk Assessment

- Provide risk information necessary to assist decision-making at remedial sites
- BRA and FS effectiveness evaluations provide this information

Baseline Risk Assessment - evaluate and document potential risks to human health and the environment associated with current and predicted future exposures to site-related contaminants if no remedial action is taken

- provides basis for determining whether remediation is necessary
- represents the "No Action" alternative for the FS
- provides basis for determining residual contamination levels

RISK CHARACTERIZATION



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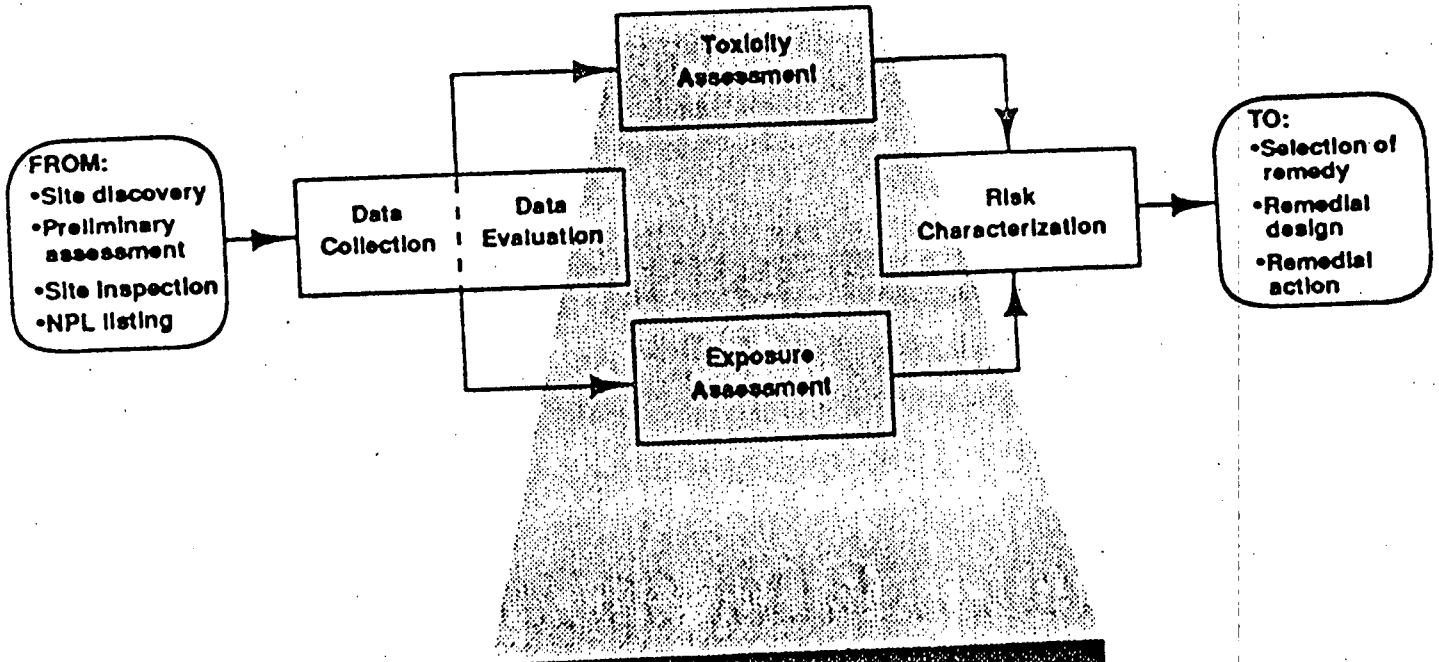
TOXICITY ASSESSMENT



TOXICITY ASSESSMENT

- Gather qualitative and quantitative toxicity information for substances being evaluated
- Identify exposure periods for which toxicity values are necessary
- Determine toxicity values for noncarcinogenic effects
- Determine toxicity values for carcinogenic effects

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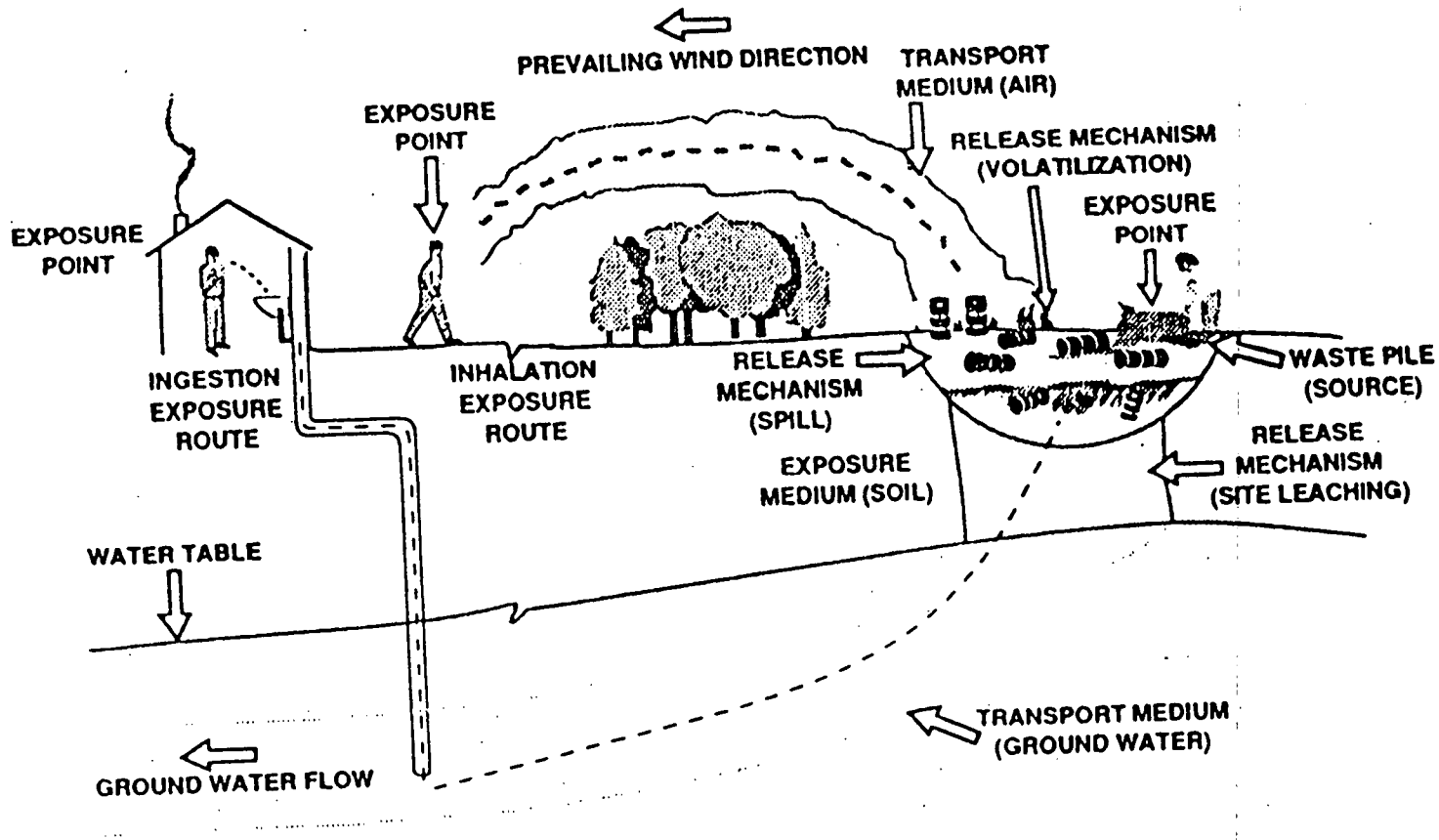
ILLUSTRATION OF EXPOSURE PATHWAYS



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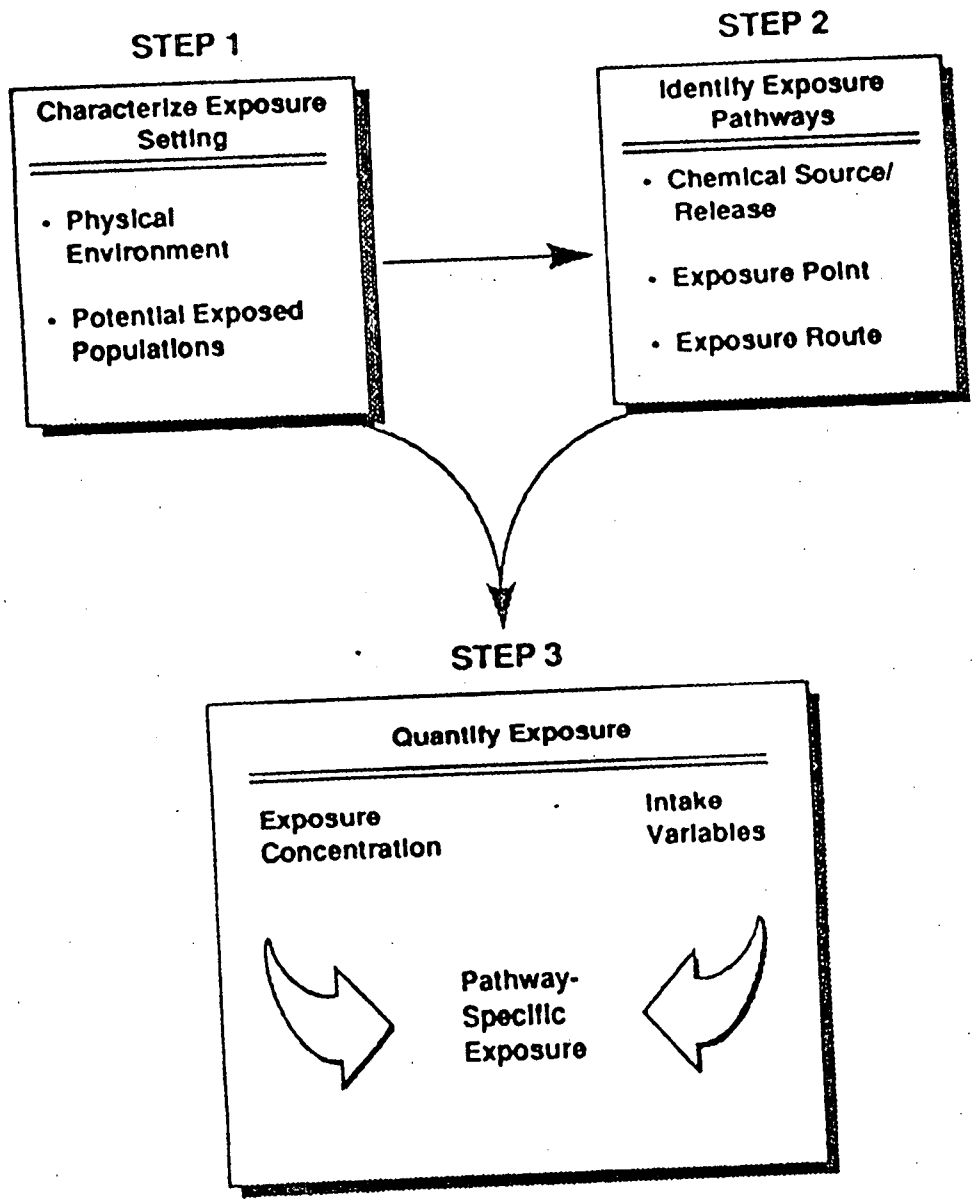
THE EXPOSURE ASSESSMENT PROCESS



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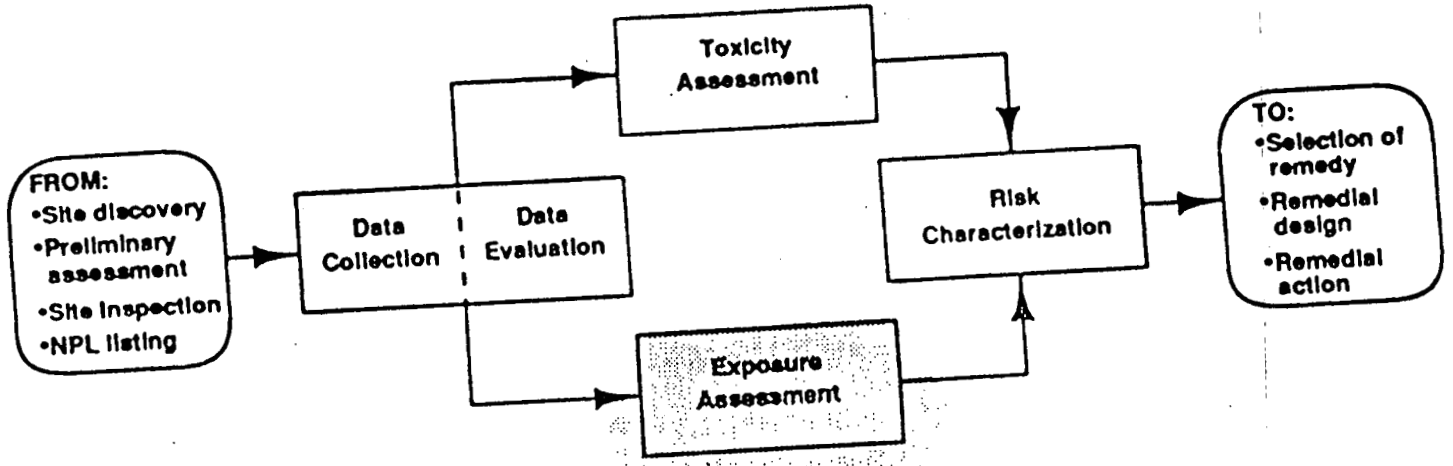
EXPOSURE ASSESSMENT



EXPOSURE ASSESSMENT

- Characterize physical setting
- Identify potential exposed populations
- Identify potential exposure pathways
- Estimate exposure concentrations
- Estimate chemical intakes

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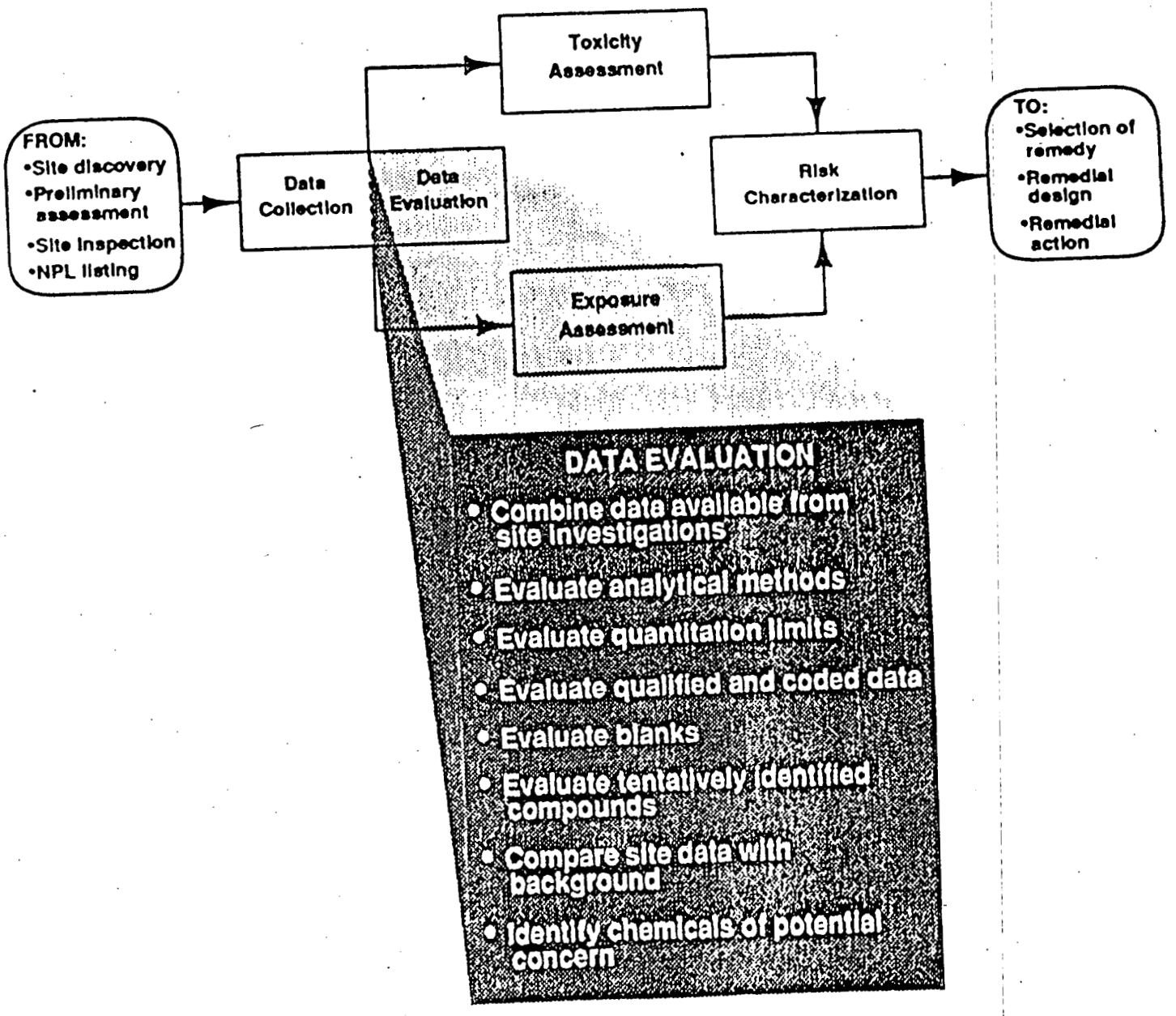
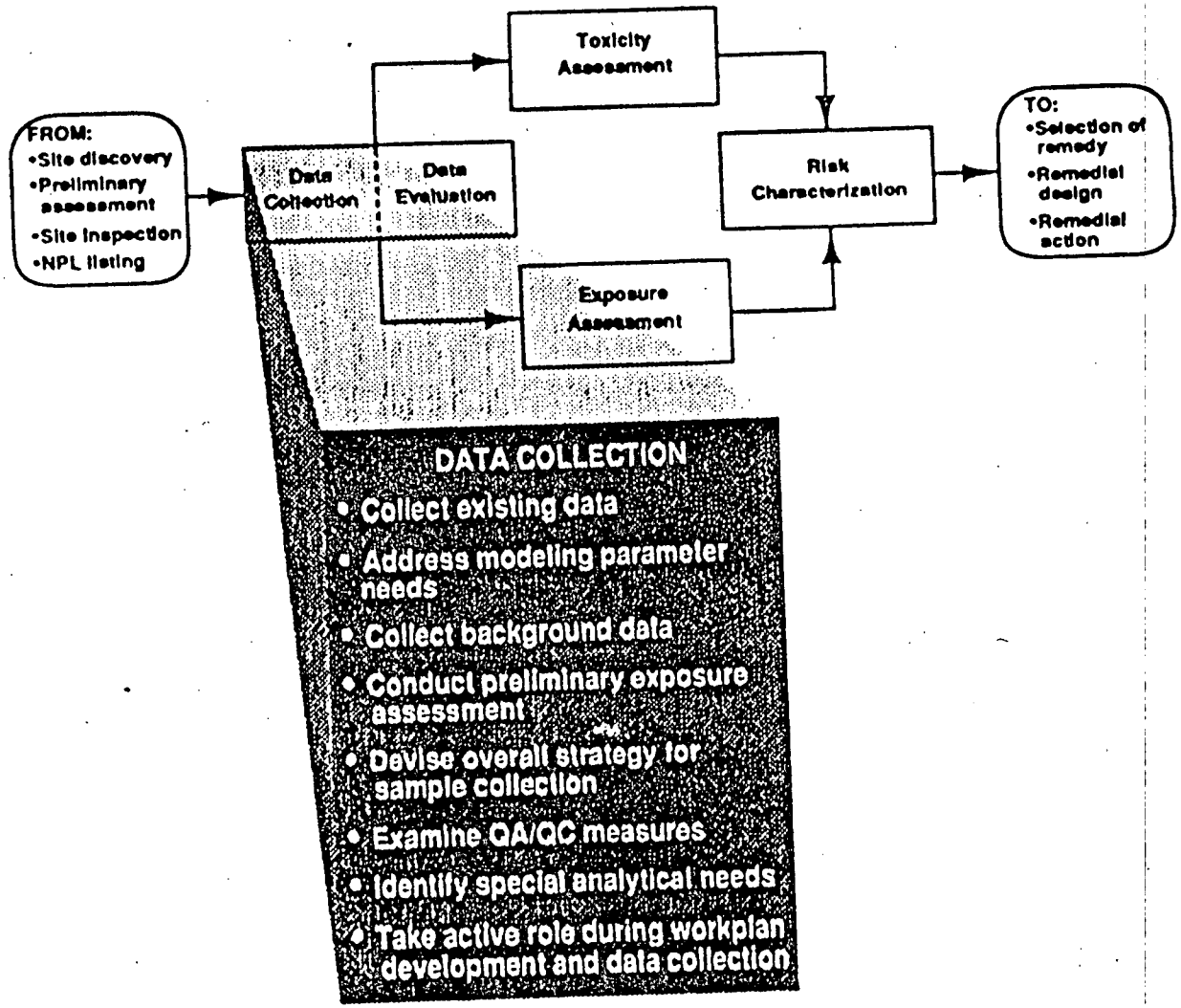
DATA EVALUATION



DATA COLLECTION



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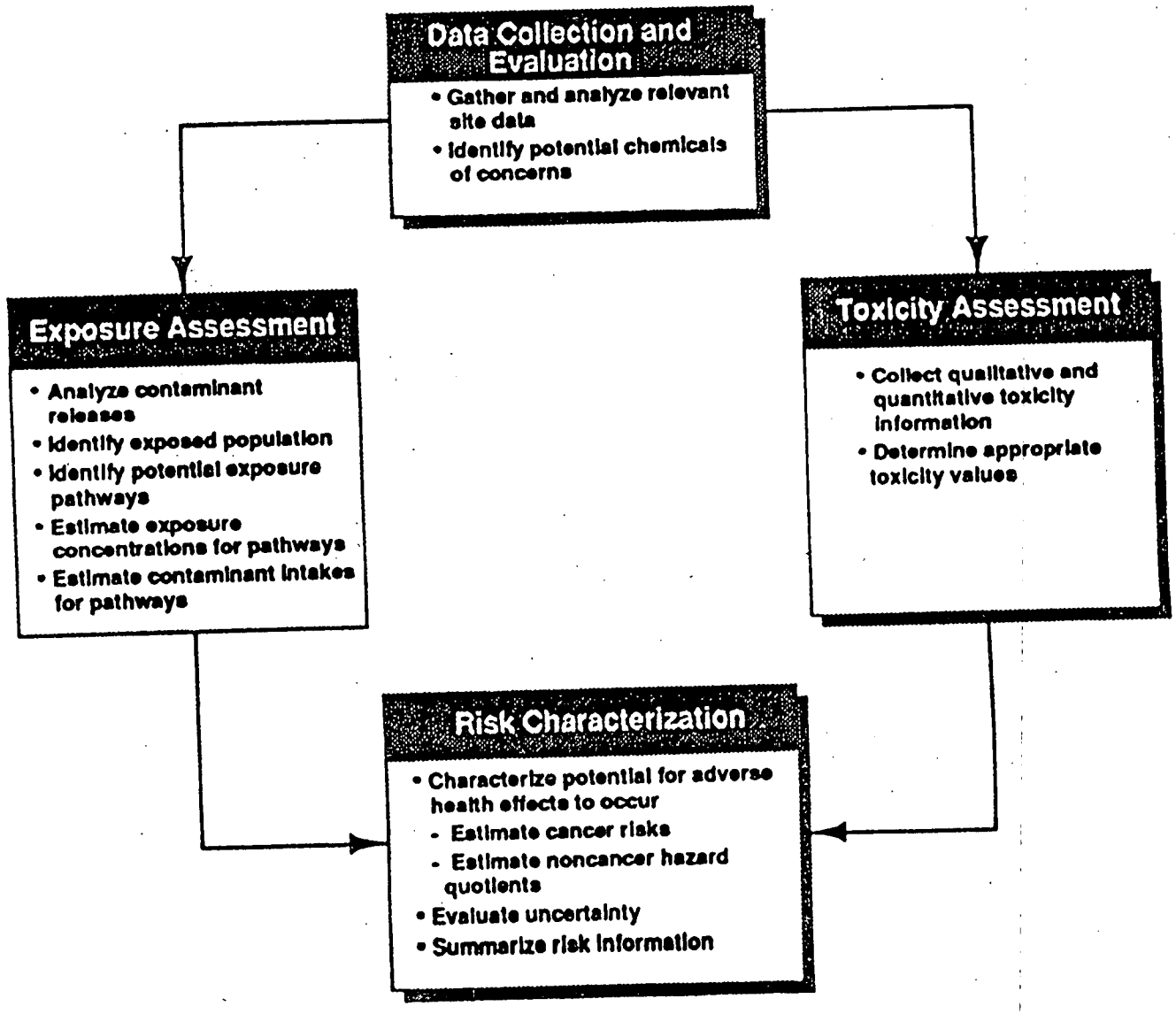
BASELINE RISK ASSESSMENT



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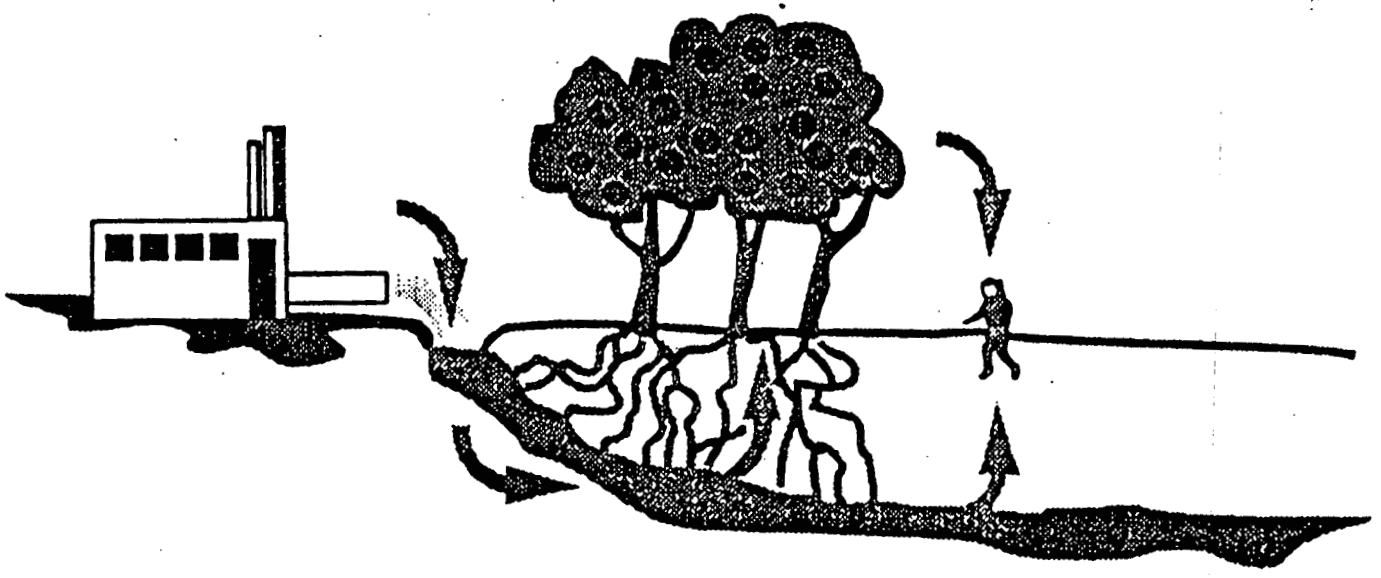
THE BASELINE RISK ASSESSMENT: ASSESSING EXPOSURE



- WHO?
- WHERE?
- HOW MUCH?

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RISK ASSESSMENT ROUNDTABLE

March 23, 1993

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RISK ASSESSMENT IN SUPERFUND

- CONSISTENT FRAMEWORK FOR DEVELOPING RISK INFORMATION NECESSARY TO ASSIST DECISION-MAKING

- PURPOSE OF RISK ASSESSMENT:

  - DETERMINE WHETHER REMEDIAL ACTION IS NECESSARY
  - HELP PROVIDE JUSTIFICATION FOR PERFORMING REMEDIAL ACTION
  - ASSIST IN DETERMINING WHAT EXPOSURE PATHWAYS NEED TO BE ADDRESSED BY REMEDIAL ACTION

- ADDRESSES BOTH HUMAN AND ECOLOGICAL RISKS

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Environmental *RISK* Management

BRIDGING THE GAP
BETWEEN
Technical Issues and Social Concerns

The Social and Political Dynamics of Risk Communication

VIDEOCONFERENCE TRAINING SERIES

Program 3

This Program Corresponds to Tapes 7 - 9

Identifying the Gap: Divergent Technical & Social Models for Risk Characterization

Air Date: April 14, 1993

Lead Presenter: Bruce J. Kelman, Ph.D., D.A.B.T.

Presented by

Waste-management Education and Research Consortium

Composed of

New Mexico State University • University of New Mexico • New Mexico Institute of Mining and Technology • Navajo Community College • U.S. Department of Energy Sandia National Laboratories • Los Alamos National Laboratory

This WERC Videoconference series is another training and education initiative of the U.S. Department of Energy.

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220030

- Operable Unit 3

  - Production Area (equipment and structures)
  - Utilities
  - Drums and Tanks
  - Effluent Lines
  - K-65 Transfer Line
  - Wastewater Treatment Facilities
  - Scrap Metal Piles
  - Product, By-Products, and Thorium Inventory

- Operable Unit 4

  - K-65 Silos (Silos 1 and 2)
  - Metal Oxide Silo (Silo 3)
  - Decant Sump System
  - Berms

- Operable Unit 5

  - All Contaminated Surface and Subsurface Soils
  - Perched Groundwater
  - Aquifer
  - Surface Water
  - Sediments
  - Flora and Fauna

1993 Broadcast Dates

JANUARY

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● *Facilitators* ■ *RISK* ▲ *RAD*

Program Description

Technical and social models for risk characterization differ greatly. Once these models are defined and understood, effective strategies for risk communication can be developed. This program will describe the divergent technical and social models for risk characterization. The discussions will include natural and technological risks, distribution of risks, and social amplification of risk. The Risk du Jour feature will highlight risk concepts from the Goiania incident, which involved an accidental release of Cesium-137 that resulted in serious social and economic impacts for the Goiania region.

Intended Audience

This series will benefit site managers, engineers, scientists, business people, teachers, and students who are concerned about or responsible for risk management activities and seek to develop an understanding of the interaction between technological risks and social processes. Those new to the field will learn basic concepts, methodology, and applications. For those already involved in risk-related activities, this program will offer an integrated approach to addressing both the social and technical aspects of risk.

Editorial Responsibility

The regulatory interpretive information provided by presenters represents the views of the individual presenter and does not constitute an endorsement by regulatory agencies or personnel. The regulations are complicated, constantly changing, and subject to differing interpretations over time; presentations necessarily represent a simplification of this complex body of information. Thus, the materials presented should not be relied upon for compliance or enforcement actions. The original regulatory material should always be consulted, as should the appropriate regulatory agencies.

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Program Introduction

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Notes:

Risk du Jour
The Goiania Incident

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Notes:

Technical Models for Risk Characterization

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Notes:

Definitions of Risk

- The formal definition of risk is:
  "The combination of probability that an undesired event will occur and the consequences resulting from the undesired event."
- Classical:
  - Risk = Probability x Consequences
  - Probability vs. consequence
- Others:
  - Reliability
  - Economics

2b

Notes:

Risk Characterization

- ❑ Risk characterization tools
  - Probabilistic risk assessment (PRA)
  - Performance assessment
  - Reliability analysis
  - Decision analysis
- ❑ Risk measures
  - Economic risks
  - Health risks
  - Environmental risks

3a

Notes:

Elements of Risk Characterization

- ❑ System familiarization
- ❑ Identify/quantify failure mechanisms.
  - Failure modes and effects analysis (FMEA)
  - Probability of failure/failure rates
- ❑ Development of system model(s)
  - Fault trees
  - Block diagrams
- ❑ Analysis of system performance
  - Risk/reliability
  - Safety
- ❑ Uncertainty/importance analysis

3b

Notes:

Emerging Uses of Risk Assessment

- Office of Management and Budget
  - Proposed requirement for risk-based budgeting
- Nuclear weapons safety
  - PRAs for all weapons, DOE, Air Force
  - Basis for safety decisions
- Department of Energy
  - PRAs for hazardous facilities
  - Waste management performance assessment
  - Comparison of sites for remediation

4a

Notes:

Emerging Uses of Risk Assessment *(cont'd)*

- Semiconductor industry
  - Equipment reliability
- Health care
  - New medical technology
  - Reduction in health-care costs

4b

Notes:

Risk Characterization Example – Performance Assessment of Radioactive Waste Repositories

Performance Assessment Definition:

"The process of quantitatively evaluating the ability of a disposal system to contain and isolate radioactive waste"

- ❑ Used to support development of a repository
- ❑ Used to determine compliance with applicable regulations
- ❑ EPA and NRC require use of a performance assessment.

5a

Notes:

Elements of a Performance Assessment

- ❑ Procedures for scenario development
  - Events and processes that could disrupt a geologic repository
  - Determine probabilities of scenario occurrence.
- ❑ Models for use in estimating consequences
  - Waste package
  - Repository
  - Groundwater flow and radionuclide transport
  - Health effects

5b

Notes:

Elements of a Performance Assessment

(cont'd)

- Regulatory compliance assessment
  - EPA
  - NRC

6a

Notes:

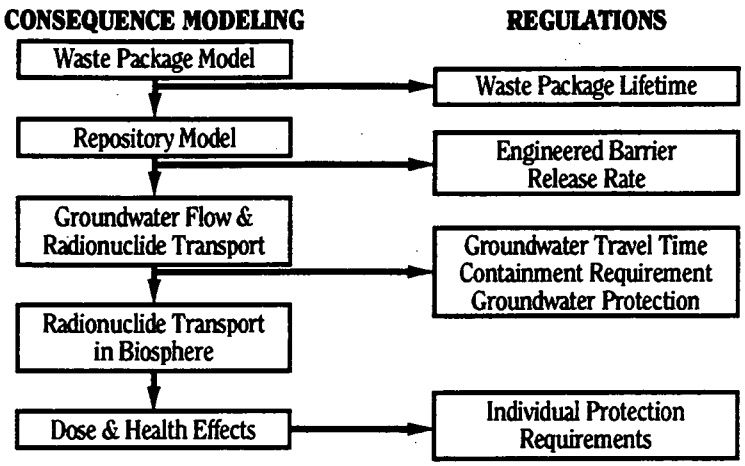
Regulatory Requirements

- EPA Environmental Standards (40 CFR 191)
  - Containment requirements
  - Individual protection requirements
  - Groundwater protection requirements
- NRC Regulations
  - Minimum waste package lifetime
  - Maximum radionuclide release rate
  - Minimum groundwater travel time

6b

Notes:

Consequence Modeling Sequence/ Points of Compliance Assessment with EPA and NRC Regulations



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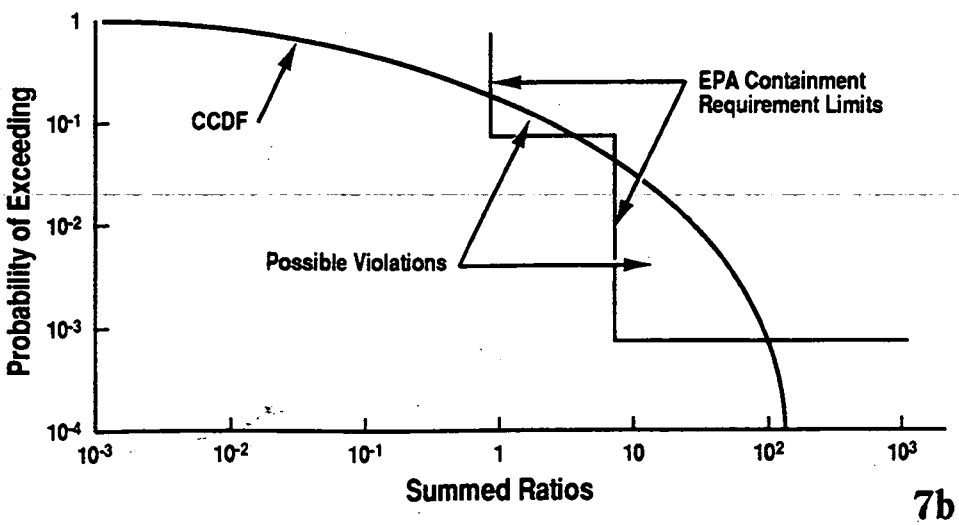
Notes:

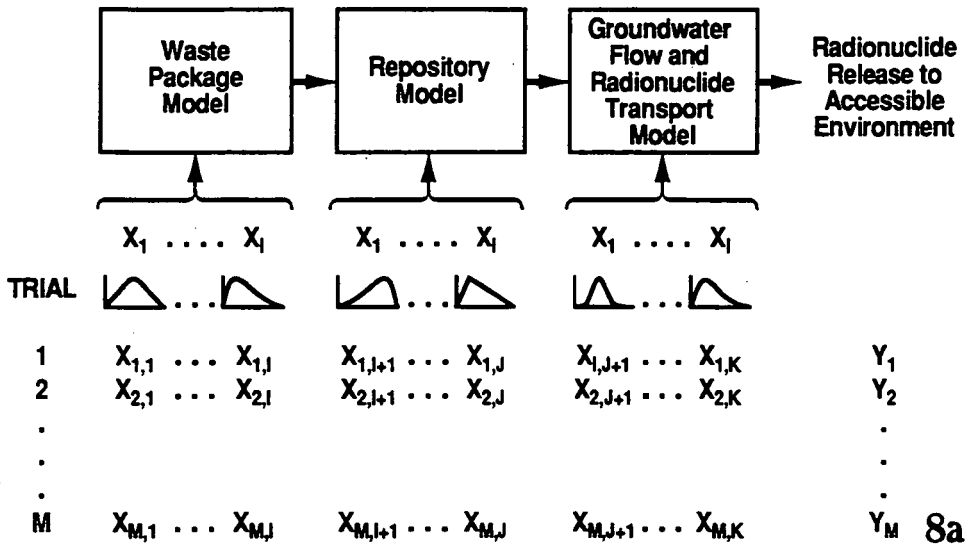
EPA Containment Requirements Assessment



7b

Notes:

Treatment of Data Uncertainty in Consequence Modeling



8a

Notes:

Risk Characterization Example – Risk/ Reliability Assessment of Burn Diagnostic and Laser Debridement System

Objective: Perform reliability and system safety analysis to provide overall safety assurance to the integrated Burn Diagnostic and Laser Debridement Systems (BDLDS)

- ❑ Analyze failure mechanisms (FMEA).
- ❑ Understand risks associated with failures.
- ❑ Develop model(s) of system.
- ❑ Evaluate design tradeoffs with cost/benefit analysis.
- ❑ Provide insights into system improvements.

8b

Notes:

Burn Debridement

- Subsystems
  - Laser
    - Spot size, scan rate, power
    - Closed-loop tracking
    - E-stop circuit
    - Safety
  - Robot (automation)
    - Closed-loop service control
    - Manual position mode
    - Safety

9a

Notes:

Burn Debridement *(cont'd)*

- Imaging (diagnostic)
  - Indocyanine green
  - 3D mapping
  - Options
- World model
  - Laser/tissue model
  - Reliability/risk assessment

9b

Notes:

Burn Debridement *(cont'd)*

- Systems
  - Supervisory control
  - Generic intelligent system controller (GISC)
    - Modular subsystems
  - Robot independent programming environment (RIPE)
  - Robot independent programming language (RIPL)
  - Model based control
  - Sensor based control

10a

Notes:

Summary

- Technical models for risk characterization are varied.
- "Risk" can be characterized in variety of ways.
- Applications of risk analysis are spreading.
- Regulations are moving more and more to risk-based.
- Risk and reliability models are based on data to the extent possible.
- Data collection and analysis are critical parts of risk and reliability studies.

10b

Notes:

Social Models: Risk Perception

Paul Slovic, Ph.D.
Decision Research
1201 Oak Street
Eugene, OR 97401
(503) 485-2400 FAX (503) 485-2403

Notes:

Basic Thesis

- The management and regulation of hazards need to be based on an understanding of the ways in which people THINK about risk.

11b

Notes:

Risk Conflicts

- Limited science vs.
  Values
  Trust
  Fairness
  Power
  Politics
  in an adversarial system

12a

Notes:

Two Models

- Traditional model
  - Science guides risk-management policy.
- New model
  - Science and public values guide policy.

12b

Notes:

Research Effort

Science
Risk Assessment
(10,000)

Identification
Measurement

toxicology
epidemiology
engineering
analysis
meteorology
geology
microbiology
astrophysics
radiation biology
•
•
•

Management
•
(1)

Evaluation
Perception/
Communication

13a

Notes:

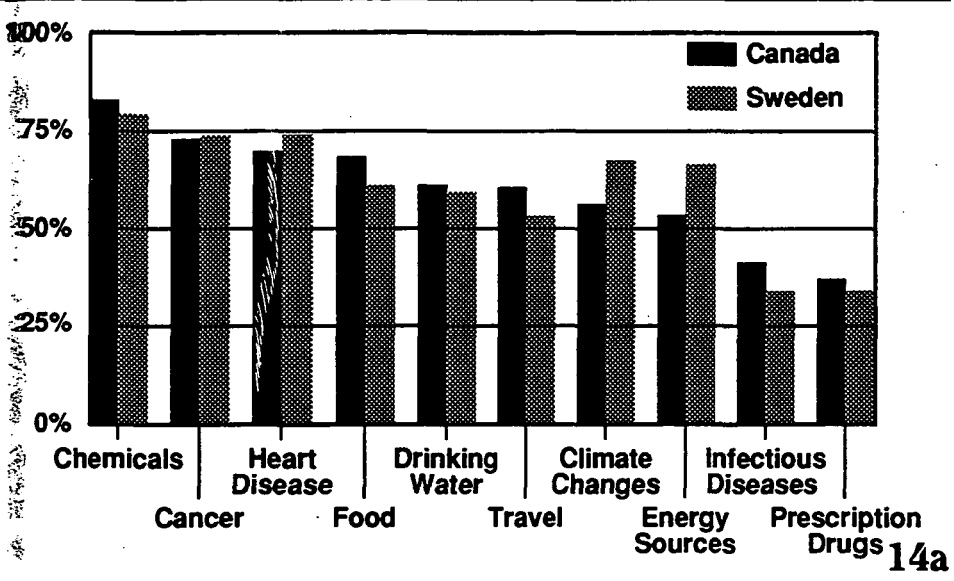
Risk Problems

- Perceived risk is a battleground marked by strong and conflicting views.
- As we have become healthier and safer on average, we have become more concerned about risk.
- Studies of risk perception attempt to understand this paradox, as well as the seemingly inconsistent attitudes across hazards (e.g., nuclear power vs. dams; chemicals vs. smoking, etc.)

13b

Notes:

Risk Today Vs. 20 Years Ago (More Risk Today)



14a

Notes:

Free-Association to the Word "Chemicals"

Chemicals _____

Chemicals _____

Chemicals _____

_____

etc. _____

Chemical Co. Executives (N = 28)

College Students (N = 50)

14b

Notes:

Public Perceptions Drive EPA's Agenda

- "Analysis of recent public polling data made it clear that EPA's actual priorities and legislative authorities correspond more closely with public opinion than they do with EPA task force's estimates of the relative risk."

Source: *EPA Journal*, Nov. 1987, pp. 9-10.

15a

Notes:

Excerpts from a 1987 Speech by Elizabeth Whelan*

- Our public health priorities in the U.S. are inverted and confused.
- As a nation in pursuit of good health we are squishing ants and letting the elephants run wild.
- This may be one of the most critical domestic issues facing the U.S. today.
- It is wasteful and unprincipled to chase after chemical residues in our food when cigarettes, AIDS, alcohol, and drug abuse are costing hundreds of thousands of lives, billions upon billions of dollars, and untold human suffering.

15b

Notes:

Excerpts From a 1987 Speech by Elizabeth Whelan* *(cont'd)*

- I believe that the growing fear of technology and the associated regulatory effort to purge our land of hypothetical risks at any cost are economic suicide.

* Executive Director, American Council on Science and Health

16a

Notes:

Factors Contributing to Increasing Perception of Risk

1. Greater ability to detect minute levels of toxic substances
*2. Increasing reliance on unfamiliar technologies
*3. Spectacular/dramatic mishaps
*4. Extensive media coverage
*5. Increasing litigation and interest group involvement
*6. Limitations of risk assessment; disputes among experts
7. Benefits taken for granted

16b

Notes:

Factors Contributing to Increasing Perception of Risk *(cont'd)*

8. Greater ability to control some elements of risk (e.g., lifestyle) – anger at involuntary exposures
9. Conservatism (risk aversion) induced by health and wealth (more to lose)
10. Real changes in the nature of today's risks
11. The destruction of trust linked to #2, 3, 4, 5, 6

17a

Notes:

Science Exacerbates Perceived Risk!*

- By demonstrating problems at high doses
- By detecting presence of "high-dose" carcinogens at minute concentrations
- By being unable to prove that low doses are safe

* Within an adversarial environment where trust is lacking

17b

Notes:

Understanding Perceived Risk

- Risk perception can be studied scientifically.
- Perceptions are quantifiable and predictable.
- Research shows the following dichotomies to be misleading

Experts		Laypersons
Risk Assessment	vs.	Risk Perception
Objective	vs.	Subjective
Analytic	vs.	Intuitive/Emotional
Wise	vs.	Foolish
Rational	vs.	Irrational

18a

Notes:

Understanding Perceived Risk *(cont'd)*

- Perceptions have great social, economic, and political impacts on individuals and society.
- Link to communication

18b

Notes:

Studies of Perceived Risk

- "Risk" is left undefined.
  Rate the risk to society as a whole on a 0 - 100 scale.

Motor vehicles .....
0 100

Pesticides .....
0 100

Drugs/Medicines .....
0 100

etc.
up to 90 items

19a

Notes:

Experts vs. Laypersons Perceptions of Risk

1977 Laypersons	Rank Order	Experts
1	Nuclear Power	20
2	Motor Vehicles	1
3	Handguns	4
4	Smoking	2
↓		↓
17	Electric Power (Non-Nuclear)	9
↓		↓
22	X-Rays	7
↓		↓
30	Vaccinations	25

19b

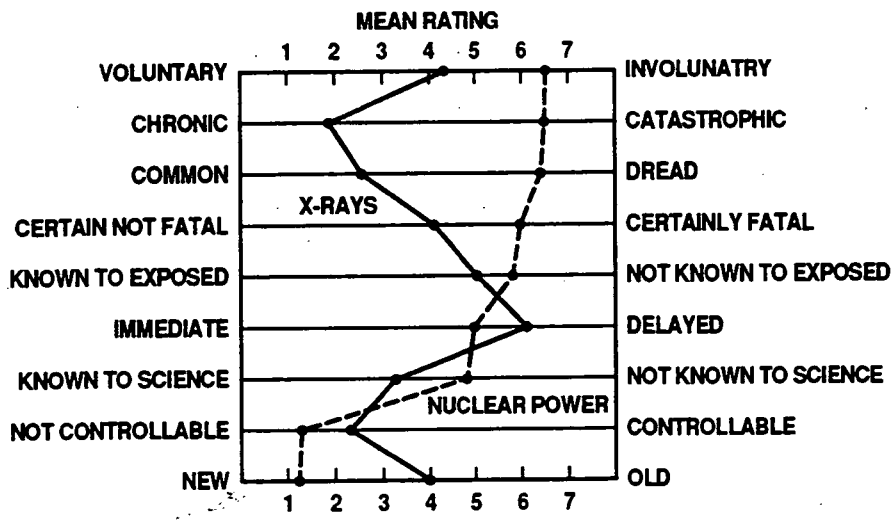
Notes:

Qualitative Risk Concerns

- ❑ Voluntary – Involuntary
- ❑ Chronic – Catastrophic
- ❑ Common – Dread
- ❑ Certainly not fatal – Certainly fatal
- ❑ Known to exposed – Not known to exposed
- ❑ Immediate – Delayed
- ❑ Known to science – Not known to science
- ❑ Not controllable – Controllable
- ❑ New – Old
- ❑ Equitable – Not equitable

20a

Notes:



20b

Notes:

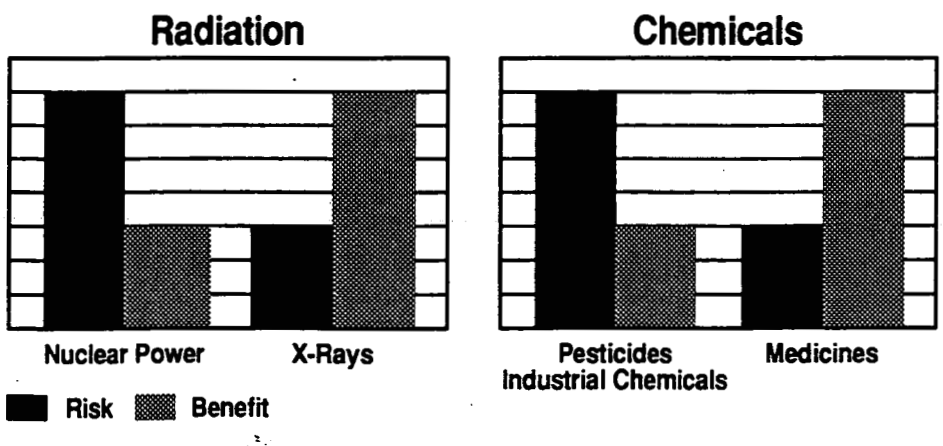
Factor Structure of Risk Perceptions

- See Appendix

21a

Notes:

Industrial vs. Medical Hazards

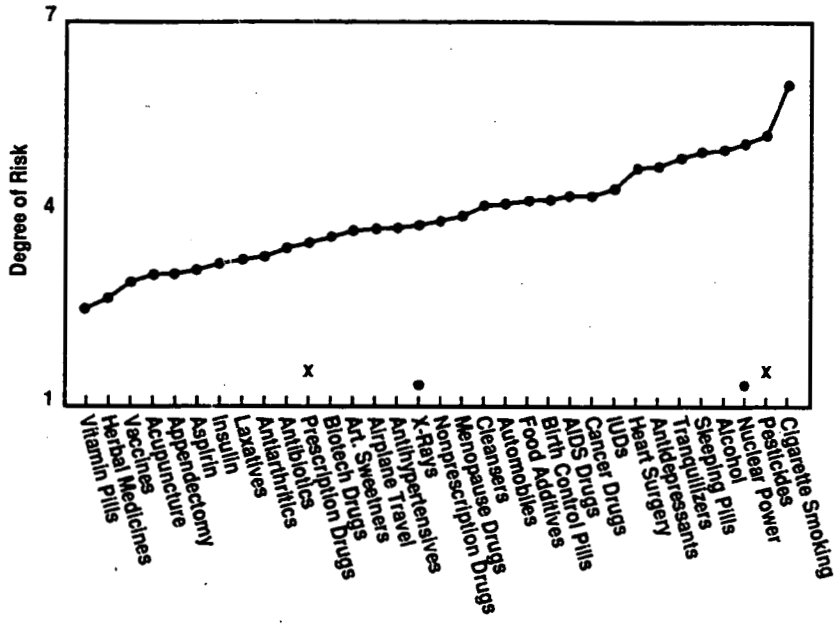


(Data from U.S., Norway, Sweden, Canada)

21b

Notes:

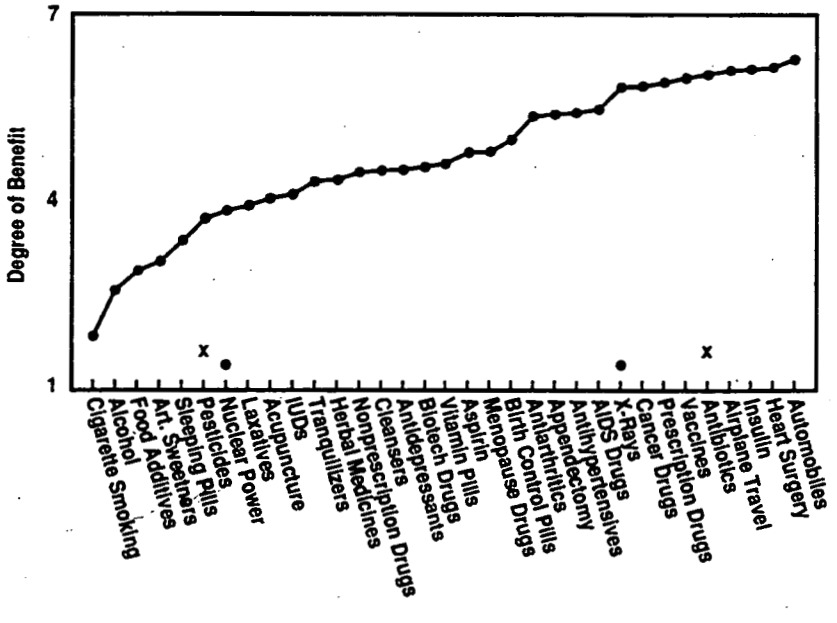
Perceived Risk



22a

Notes:

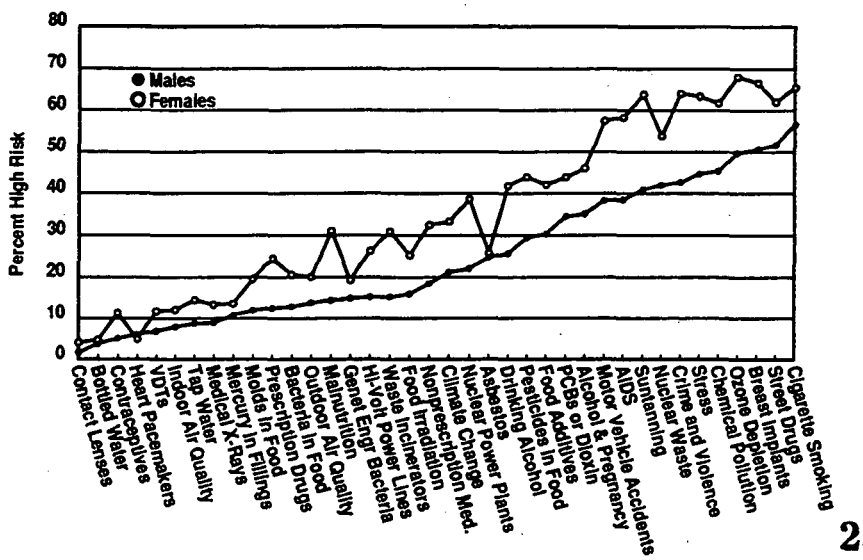
Perceived Benefit



22b

Notes:

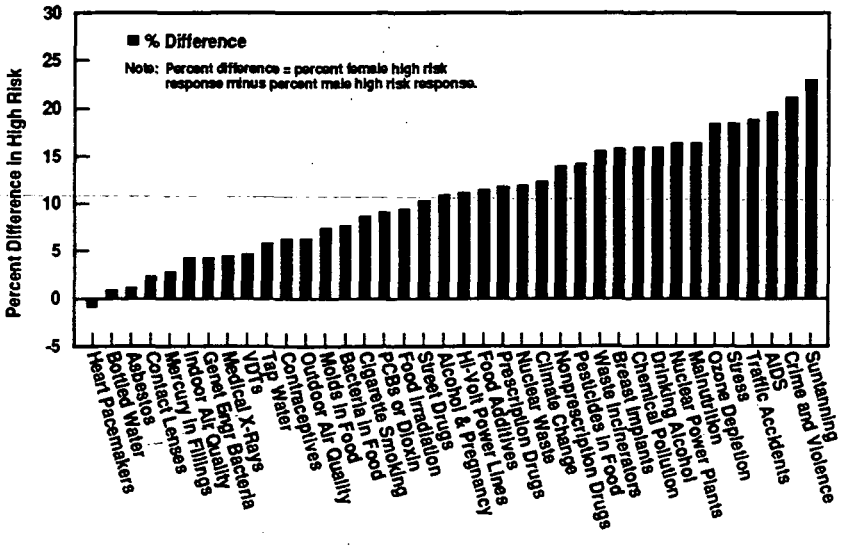
Perceived Health Risks to Canadian Public by Gender



23a

Notes:

Perceived Health Risks: Difference Between Males and Females



23b

Notes:

Perceptions Have Impacts

- ❑ Signals and ripples
- ❑ Social amplification of risk

24a

Notes:

Thesis

- ❑ Individual risk perceptions and cognitions, interacting with social and institutional forces, can trigger massive social and economic impacts due to
  - Responses to events (even "small" incidents)
  - Stigma effects

24b

Notes:

000049

Accidents Are Signals

- The perceived seriousness of a mishap, the media coverage it gets, and the long-range costs to the responsible company, industry, or agency are determined by the mishap's signal value.

25a

Notes:

Accidents Are Signals *(cont'd)*

- Signal value reflects perceptions that the event provides new information about the likelihood of similar or more destructive future mishaps.

25b

Notes:

Accidents Are Signals *(cont'd)*

- High signal events: TMI, Bhopal, DC-10, Tylenol, Alar

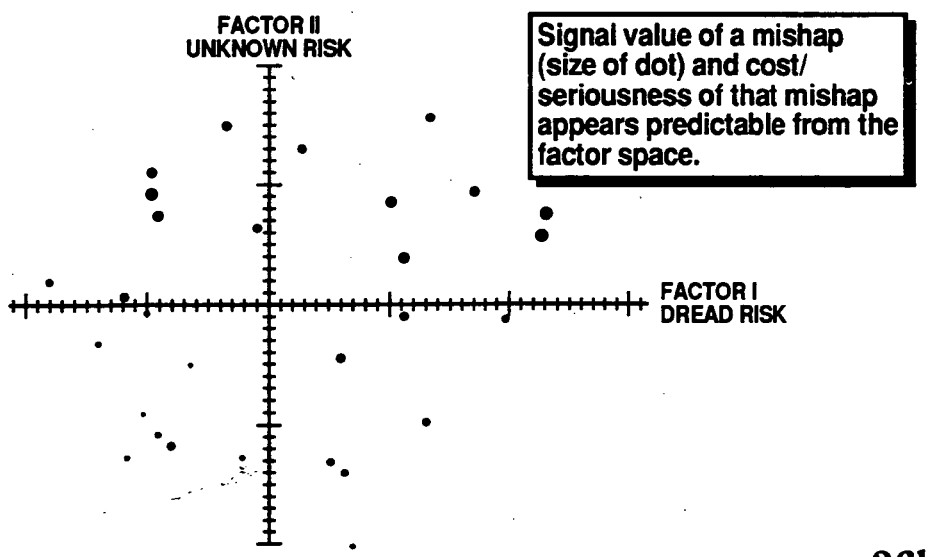
  "What truly grips us in these accounts (of disaster) is not so much the numbers as the spectacle of suddenly vanishing competence, of men utterly routed by technology, of fail-safe systems failing...and the spectacle haunts us because it seems to carry allegorical import, like the whispery omen of a hovering future."

  - *The New Yorker*, 2-18-85

26a

Notes:

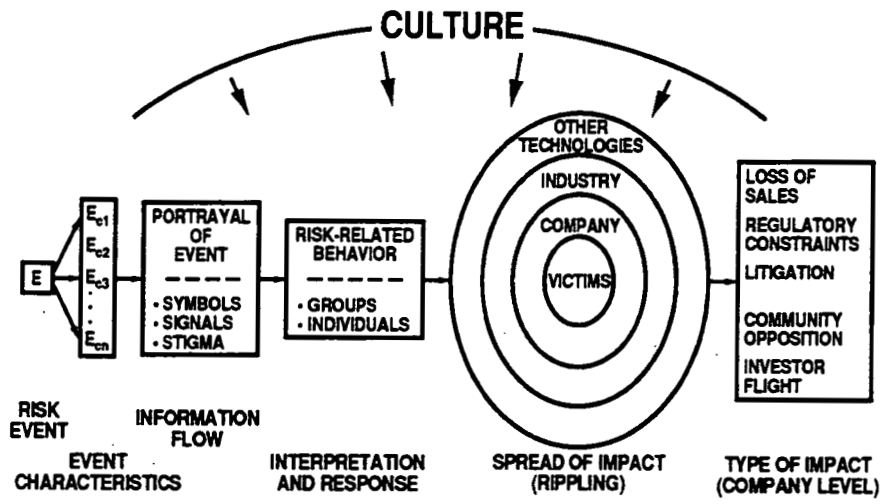
Accidents As Signals



26b

Notes:

Environmental *RISK* Management



Highly simplified representation of the social amplification of risk and potential impacts on a corporation

27a

Notes:

Policy Implications of Social Amplification

- "Extra" protection worthwhile
  - Prevent rather than just contain accidents.
  - Remote siting
  - Dedicated trains
  - Tamper-resistant packaging

27b

Notes:

Summary

- Experts and lay people conceptualize risk differently.
  - Experts view risk quantitatively, as probability x magnitude of loss.
  - Lay people take many qualitative considerations into consideration in defining risk.

28a

Notes:

Summary *(cont'd)*

- These qualitative concerns can predict societal responses toward hazards.
  - Perceptions of risk
  - Attitudes towards regulation of a hazard
    - Response to an accident or mishap
    - Media coverage
    - Ripple effects: lawsuits, stricter regulations, etc.

28b

Notes:

"Acceptance of any risk is more dependent on public confidence in risk management than on quantitative estimates of risk."

C. Starr

29a

Notes:

The Problem of Trust

- Lack of trust
  - A consequence of "the system" and events
  - A cause of the perception problem
  - Not unique to nuclear power
  - All major U.S. institutions except TV news have declined in trustworthiness since 1965.

29b

Notes:

Trust Is Fragile

"If you once forfeit the confidence of your fellow citizens, you can never regain their respect and esteem."

A. Lincoln

30a

Notes:

Trust: The Asymmetry Principle

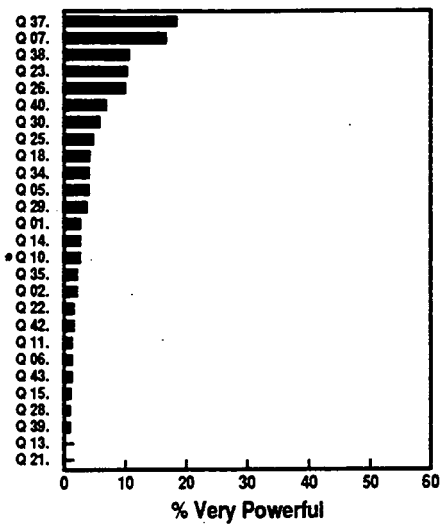
- It is far easier to destroy trust than to create it!
  - Negative (trust destroying) events outweigh positive events.
  - Negative events more sharply defined (accidents, lies).
  - Positive events often fuzzy or indistinct
    - For example, how many positive events are represented by the safe operation of a nuclear power plant for one day?
  - Sources of bad news are more credible than sources of good news.
  - Risk is easier to demonstrate than safety.

30b

Notes:

000055

Increased Trust

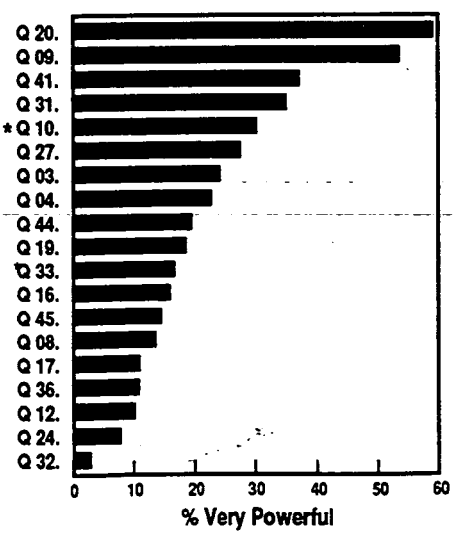


Q 37. Local board authority to close plant
Q 07. Responsive to any sign of problems
Q 38. Evacuation plan exists
Q 23. On-site government inspector
Q 26. Rewarded for finding problems
Q 40. Effective emergency action taken
Q 30. Local advisory board established
Q 25. Public encouraged to tour plant
Q 18. Mandatory drug testing
Q 34. No problems for five years
Q 05. Hold regular public hearings
Q 29. Employees carefully trained
Q 01. Conduct emergency training
Q 14. Community has access to records
• Q 10. Serious accident is controlled
Q 35. Nearby health is good
Q 02. Monitor radioactive emissions
Q 22. Employees informed of problems
Q 42. Neighbors notified of problems
Q 11. Record keeping is good
Q 06. No evidence of withholding information
Q 43. Contribute to local charities
Q 15. Employees closely supervised
Q 28. Try to meet with public
Q 39. Managers live nearby
Q 13. Operates according to regulations

31a

Notes:

Decreased Trust



Q 20. Records found falsified
Q 09. Employees drunk on job
Q 41. Plant covered up problem
Q 31. No adequate emergency response plan
• Q 10. Serious accident is controlled
Q 27. Official lied to government
Q 03. Health nearby worse than average
Q 04. Public tours not permitted
Q 44. Delayed inspections
Q 19. Employees not informed of problems
Q 33. Denied access to records
Q 16. Accused of releasing radiation
Q 45. Accident occurs in another state
Q 08. Poor record keeping
Q 17. Officials live far away
Q 36. Emergency response plans not rehearsed
Q 12. Little communication with community
Q 24. No public hearings
Q 32. Don't contribute to local charities

31b

Notes:

Many Factors Work to Obliterate Trust

- ❑ Media reporting of problems worldwide
  - In nuclear and related industries
- ❑ Adversarial risk management system
  - Litigation
  - Expert vs. expert
  - Special interest groups keep problems in the "spotlight."

32a

Notes:

Many Factors Work to Obliterate Trust *(cont'd)*

- ❑ Legacy of real problems
- ❑ Risk can be demonstrated far more easily than safety.
- ❑ Distrust fuels distrust.
  - Limits contacts that could --> trust
  - Colors our interpretation of events

32b

Notes:

Trust!

- ❑ Confront the problem
  - Top priority
  - Goes beyond any one industry
    - Chemicals
    - Nuclear power
    - Biotech
- ❑ Problem not merely ignorance or irrationality
- ❑ Public relations won't produce trust.
- ❑ Risk communication won't work without it.
- ❑ To date, there has been remarkably little research on the topic of trust.

33a

Notes:

Notes:

Divergent Approaches to Cancer Risk Regulation

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Notes:

FDA and the Delaney Clause

- Delaney Clause enacted as part of Food Additives Amendment to Federal Food, Drug, and Cosmetic Act in 1958
- Essentially prohibits the addition of any human or animal carcinogen to the human food supply (i.e., zero risk)
- In practice, lifetime cancer risks which do not exceed one in a million are considered "de minimis" and are ignored (controversial).

34b

Notes:

Handling Risk Within OSHA

Example: Reduction of the PEL

- ❑ Rationale
  - Reasonable expectation that workers will suffer material impairment of health under the existing standard
- ❑ Obligation
  - Establish a new PEL which represents the lowest level felt to be economically and technologically feasible in the most marginal segment of the industry affected by the new standard.

35a

Notes:

Handling Risk Within OSHA *(cont'd)*

- ❑ Reality
  - For all new PELs promulgated by OSHA since 1983 (all carcinogens), the lowest feasible risk has exceeded 1 per 1,000.

35b

Notes:

Handling Risk Within OSHA *(cont'd)*

- PEL for asbestos was reduced from 2.0 to 0.2 fibers/cc of air in 1986.
- Estimated asbestos-related cancer mortality for 45-year exposure

PEL (f/cc)	Mortality (/1,000)
2.0	64
0.2	6.7

- OSHA estimated
  - Reduction of the PEL would prevent 75 cancer deaths per year.
  - Annual compliance costs for affected industries: $460,000,000

36a

Notes:

EPA Groundwater Remediation Under Superfund

According to the NCP (1990)

- Groundwater that is or could be used for drinking generally will be restored to the MCLG when it is above zero.
- When the MCLG equals zero (most carcinogens), the MCL will be used as the cleanup level.
- Cleanup level of zero is not appropriate because
  - CERCLA does not require the complete elimination of risk.
  - It is impossible to detect whether true zero has been attained.

36b

Notes:

000061

EPA Groundwater Remediation Under Superfund *(cont'd)*

- NCP sets the acceptable risk range between 10^{-4} (1 in 10,000) and 10^{-6} (1 in 1 million) with the point of departure at 10^{-6}.
- In practical terms, the MCL, equivalent to a risk of 1 in 1 million, will become the cleanup level.

37a

Notes:

Dealing with Radiation Risk

International Commission on Radiological Protection (ICRP)

- Excess environmental radiation (i.e., net exposure above background) should be limited to 100 mrem/year for the general population.
- Exposure should be as low as reasonably achievable (ALARA).
- Technologies causing exposures should have a net positive benefit (social and economic).

37b

Notes:

Dealing with Radiation Risk *(cont'd)*

Notes:

Problem

- ❑ Background sources could contribute exposure of 100 mrem/year. Over a 70-year lifetime, could cause 3 cancer deaths per 1,000 people exposed
- ❑ Lifetime exposure to radon at the EPA indoor exposure guideline level (4 pCi/liter) could contribute 1 rem/year, leading to 5 cancer deaths per 100 people exposed.

38a

Communication of Risk

Notes:

- ❑ Risk of death from being hit by an airplane while on the ground (over a 70-year lifetime)
  - 4.2 in a million
- ❑ Risk of death
  - Not influenced by our skills
  - Not optional
  - Provides no benefits to anybody involved
  - Not an act of nature

38b

000063

Communication of Risk *(cont'd)*

- As public/private citizens, we could modify the risks; however, such an action would be unlikely given the magnitude of the risk.

Adapted from "Risk to Groundlings of Death Due to Airplanes: A Risk Communication Tool," B.D. Goldstein, M. Demak, M. Northridge, D. Wartenberg. *Risk Analysis*, Vol. 12 (1992) 339-341.

39a

Notes:

Notes:

Notes:

Naturally-Occurring and Man-Made Carcinogens

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Berkeley, CA 94720
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Notes: See Special Section

000065

The Mass Media and the "Social Amplification of Risk"

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Notes:

The Argument

- The mass media misunderstand, misrepresent, amplify, sensationalize and trivialize risk and risk assessment, and generally confuse a gullible public.

41b

Notes:

The Problem

- ❑ Journalists are generalists: liberal arts majors mostly.
- ❑ Competitive pressure
- ❑ Get it now! Sort it out later.
- ❑ Watchdogging: don't trust nobody.
- ❑ Go with the underdog: the regular folks.

42a

Notes:

The Safeguards

- ❑ You ain't gonna believe this: We try like hell.
- ❑ Ethics: What we believe
- ❑ Objectivity: Who we talk to
  - The researchers
  - The critics
  - The doers
  - Oxes that might get gored

42b

Notes:

The Background

- ❑ Too much denial: tobacco
- ❑ Too many deaths: asbestos
- ❑ Too much frenzy: sweeteners
- ❑ Too much nonsense: alar
- ❑ Too little benefit: artificial coloring
- ❑ Too little action: cholera
- ❑ Too much confusion: Three Mile Island
- ❑ Too little attention: heart disease and accidents

43a

Notes:

The Questions

- ❑ Whose risk?...Whose benefit?
- ❑ Who gets to choose?
- ❑ How much risk is acceptable?
  (One in a million is 100% if it's my kid.)
- ❑ Can risk be reduced more? Is "pretty low" low enough?
- ❑ Can we put faces on the risk...and the benefit?

43b

Notes:

The Answers

- Talk to us. Don't hide behind statistics, but make the uncertainty clear.
- Never lie. In the end you get caught, and the price of distrust is high.
- Provide your experts, not just public relations people.
- Be frank: concede what you don't know.
- Be human: imagine it's your home, your kid, your cancer.
- NEVER overstate safety levels.

44a

Notes:

The End

- The media reflect the attitudes and biases of the public much more than they shape it.
- Our concern rests much more with people than with institutions.
- Problems don't go away just because the media don't report them.

44b

Notes:

Environmental Racism

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Notes:

Introduction/Overview

- History of environmental racism
- Terminology
- Changing social and political context
- Legal context
- Alternatives in dealing with changing context

45b

Notes:

History of Environmental Racism

- 1982 – Siting of PCB landfill
- 1983 – U.S. General Accounting Office (GAO) study
- 1987 – United Church of Christ, Commission for Racial Justice Report
- 1987 – Reverend Benjamin Chavis Jr., United Church of Christ

46a

Notes:

Terminology – Racism

- Highly charged
- "Apparent" meaning
- Applied to activities and outcomes
- Verbal inflation

46b

Notes:

Terminology – Racism *(cont'd)*

- ❑ Structural oppression
- ❑ Domination and subordination
- ❑ Need not be intentional
- ❑ Unconscious
- ❑ Color-blindness of the law

47a

Notes:

Changing Social and Political Context

- ❑ Paradigm shift
- ❑ Culture
  - Ways of aggregating facts
  - Ways of interpreting reality
- ❑ Pollution creation and its control and disposal are culturally generated phenomena.

47b

Notes:

Changing Social and Political Context

(cont'd)

- ❑ Sociological
- ❑ Psychological
- ❑ Spiritual
- ❑ Scientific/technological
- ❑ Legal

48a

Notes:

Changing Social and Political Context

(cont'd)

- ❑ NIMBY not in my backyard
- ❑ PIBBY place in blacks' backyard
- ❑ PIMBY place in minorities' backyard
- ❑ NIMTOF not in my term of office
- ❑ NIMEY not in my election year
- ❑ LULU locally unwanted land uses
- ❑ CAVE citizens against virtually everything

48b

Notes:

Legal Context

- Equal protection clause of the fourteenth amendment
- Civil Rights Act of 1866 – Section 1983

49a

Notes:

Legal Context *(cont'd)*

- Respect for legitimate property rights
- Greater cultural sensitivity
- Sustainable development
- Subsidies

49b

Notes:

Alternatives in Dealing with Changing Context

- ❑ Overcome local hostility.
- ❑ Appease local concerns.
- ❑ By-pass local opposition.

50a

Notes:

Alternatives in Dealing with Changing Context *(cont'd)*

- ❑ Super review
- ❑ Site designation
- ❑ Local control
- ❑ Incentives approach

50b

Notes:

000075

Notes:

Conflict on the Rio Grande Water Use on the Isleta Pueblo

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(505) 277-1689 FAX (505) 277-0813

Notes:

Proc. Natl. Acad. Sci. USA
Vol. 87, pp. 7777-7781, October 1990
Medical Sciences

Procedures of the National Academy of Sciences
Vol. 87, pp 7777-7781, Oct. 1990

Dietary pesticides (99.99% all natural)*

(carcinogens/mutagens/clastogens/coffee)

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Contributed by Bruce N. Ames, July 19, 1990

ABSTRACT **The toxicological significance of exposures to synthetic chemicals is examined in the context of exposures to naturally occurring chemicals. We calculate that 99.99% (by weight) of the pesticides in the American diet are chemicals that plants produce to defend themselves. Only 52 natural pesticides have been tested in high-dose animal cancer tests, and about half (27) are rodent carcinogens; these 27 are shown to be present in many common foods. We conclude that natural and synethic chemicals are equally likely to be positive in animal cancer tests. We also conclude that at the low doses of most human exposures the comparative hazards of synthetic pesticide residues are insignificant.**

Toxicological examination of synthetic chemicals such as pesticides and industrial pollutants, without similar examination of the chemicals in the natural world to use for comparison, has generated an imbalance in both data and perception about potential hazards to humans (1-6). In this and two accompanying papers (7, 8), we try to redress this imbalance and discuss in detail one major group of natural chemicals in our diet—nature's pesticides.

About half of all chemicals (whether natural or synthetic) tested chronically in animal cancer tests at the maximum tolerated dose (MTD) are carcinogens (7, 9-14).¶ The MTD of the test chemical is a near-toxic dose that can cause chronic mitogenesis, often as a result of cell killing (7). We have argued that mitogenesis increases mutagenesis, and therefore that a high percentage of all chemicals might be expected to be carcinogenic when tested chronically at the MTD (7). A high proportion of both natural and synthetic test chemicals are positive for carcinogenicity. Natural chemicals constitute the vast bulk of chemicals in the human diet and therefore should be used as a reference for evaluating possible carcinogenic hazards from synthetic chemicals. In recent years, we have compared the possible hazards of various rodent carcinogens, using the human exposure/rodent potency (HERP) ratio (1, 6). It should be emphasized that as the understanding of carcinogenesis mechanisms improves, these comparisons can be refined but they cannot provide a direct estimate of human hazard. This paper does not extend the HERP comparisons (1) because our purpose is different and space does not allow a proper analysis.

Nature's Pesticides: Mutagenicity and Carcinogenicity

Plants are not just food for animals.... The world is not green. It is colored lectin, tannin, cyanide, caffeine, aflatoxin, and canavanine [Janzen (16)].

Dietary Pesticides Are 99.99% All Natural. Nature's pesticides are one important subset of natural chemicals. Plants produce toxins to protect themselves against fungi, insects, and animal predators (5, 16-23). Tens of thousands of these natural pesticides have been discovered, and every species of plant analyzed contains its own set of perhaps a few dozen toxins. When plants are stressed or damaged, such as during a pest attack, they may greatly increase their natural pesticide levels, occasionally to levels that can be acutely toxic to humans. We estimate that Americans eat about 1.5 g of natural pesticides per person per day, which is about 10,000 times more than they eat of synthetic pesticide residues (see below). As referenced in this paper (see refs. 16-21 and legends to Tables 1 and 2), there is a very large literature on natural toxins in plants and their role in plant defenses. The human intake of these toxins varies markedly with diet and would be higher in vegetarians. Our estimate of 1.5 g of natural pesticides per person per day is based on the content of toxins in the major plant foods (e.g., 13 g of roasted coffee per person per day contains about 765 mg of chlorogenic acid, neochlorogenic acid, caffeic acid, and caffeine; see refs. 22 and 23 and Table 2). Phenolics from other plants are estimated to contribute another several hundred milligrams of toxins. Flavonoids and glucosinolates account for several hundred milligrams; potato and tomato toxins may contribute another hundred, and saponins from legumes another hundred. Grains such as white flour and white rice contribute very little, but whole wheat, brown rice, and corn (maize) may contribute several hundred milligrams more. The percentage of a plant's weight that is toxin varies, but a few percent of dry weight is a reasonable estimate: e.g., 1.5% of alfalfa sprouts is canavanine and 4% of coffee beans is phenolics. However, the percentage in some plant cultivars is lower (e.g., potatoes, tomatoes).

Abbreviation: MTD, maximum tolerated dose.
*This is paper no. 2 of a series. Paper no. 1 is ref. 7.
‡To whom reprint requests should be addressed.
¶References to, and analyses of, individual cancer tests are in the Carcinogenic Potency Database papers (10-13). Our analyses are based on this database, which reports only results of chronic, long-term bioassays that are adequate to detect a carcinogenic effect or lack of effect and to estimate potency. More than 4000 experiments met the inclusion criteria of the database, but thousands of others did not: e.g., tests that lack a control group, that are too short or include too few animals to detect an effect, that use routes of administration not likely to result in whole body exposure (like skin painting or subcutaneous administration), cocarcinogenesis studies, and bioassays of particulate or fibrous matters.

One-third of the chemicals in the database have been tested by the National Cancer Institute/National Toxicology Program, using standard protocols with tests in two species at the MTD (15). About half of the chemicals in the database, however, have been tested in only one species. Positivity rates and prediction between species have been analyzed (9).

We classify the results of an experiment as either positive or negative on the basis of the authors' opinion in the published paper and classify a chemical as positive if it has been evaluated as positive by the author of at least one experiment. We use the author's opinion to determine positivity because it often takes into account more information than statistical significance alone, such as historical control rates for particular sites, survival and latency, and/or dose response. Generally, this designation by author's opinion corresponds well with the results of statistical reanalyses of the significance of the dose-response effect (9).

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Table 1. Forty-nine natural pesticides and metabolites found in cabbage

Glucosinolates: 2-propenyl glucosinolate (sinigrin),* 3-methylthiopropyl glucosinolate, 3-methylsulfinylpropyl glucosinolate, 3-butenyl glucosinolate, 2-hydroxy-3-butenyl glucosinolate, 4-methylthiobutyl glucosinolate, 4-methylsulfinylbutyl glucosinolate, 4-methylsulfonylbutyl glucosinolate, benzyl glucosinolate, 2-phenylethyl glucosinolate, propyl glucosinolate. butyl glucosinolate

Indole glucosinolates and related indoles: 3-indolylmethyl glucosinolate (glucobrassicin), 1-methoxy-3-indolylmethyl glucosinolate (neoglucobrassicin), indole-3-carbinol,* indole-3-acetonitrile, bis(3-indolyl)methane

Isothiocyanates and goitrin: allyl isothiocyanate,* 3-methylthiopropyl isothiocyanate, 3-methylsulfinylpropyl isothiocyanate, 3-butenyl isothiocyanate, 5-vinyloxazolidine-2-thione (goitrin), 4-methylthiobutyl isothiocyanate, 4-methylsulfinylbutyl isothiocyanate, 4-methylsulfonylbutyl isothiocyanate, 4-pentenyl isothiocyanate, benzyl isothiocyanate, phenylethyl isothiocyanate

Cyanides: 1-cyano-2,3-epithiopropane, 1-cyano-3,4-epithiobutane, 1-cyano-3,4-epithiopentane, *threo*-1-cyano-2-hydroxy-3,4-epithiobutane, *erythro*-1-cyano-2-hydroxy-3,4-epithiobutane, 2-phenylpropionitrile, allyl cyanide,* 1-cyano-2-hydroxy-3-butene, 1-cyano-3-methylsulfinylpropane, 1-cyano-4-methylsulfinylbutane

Terpenes: menthol, neomenthol, isomenthol, carvone*

Phenols: 2-methoxyphenol. 3-caffoylquinic acid (chlorogenic acid),* 4-caffoylquinic acid,* 5-caffoylquinic acid (neochlorogenic acid),* 4-(*p*-coumaroyl)quinic acid, 5-(*p*-coumaroyl)quinic acid, 5-feruloylquinic acid

*Discussed below: all others untested. *Clastogenicity.* Chlorogenic acid (25) and allyl isothiocyanate are positive (26). Chlorogenic acid and its metabolite caffeic acid are also mutagens (27-29), as is allyl isothiocyanate (30). *Carcinogenicity.* Allyl isothiocyanate induced papillomas of the bladder in male rats (a neoplasm that is unusually rare in control rats) and was classified by the National Toxicology Program as carcinogenic There was no evidence of carcinogenicity in mice; however, it was stated "the mice probably did not receive the MTD" (31, 32). Sinigrin (allyl glucosinolate, i.e., thioglycoside of allyl isothiocyanate) is cocarcinogenic for the rat pancreas (33). Carvone is negative in mice (34). Indole-3-acetonitrile has been shown to form a carcinogen, nitroso indole acetonitrile, in the presence of nitrite (35). Caffeic acid is a carcinogen (36, 37) and clastogen (25) and is a metabolite of its esters 3-, 4-. and 5-caffoylquinic acid (chlorogenic and neochlorogenic acid). *Metabolites.* Sinigrin gives rise to allyl isothiocyanate when raw cabbage (e.g., coleslaw) is eaten; in cooked cabbage it also is metabolized to allyl cyanide, which is untested. Indole-3-carbinol forms dimers and trimers on ingestion, which mimic dioxin (8). *Occurrence.* See refs. 18, 21, and 38-40. *Toxicology.* The mitogenic effects of goitrin (which is goitrogenic) and various organic cyanides from cabbage suggest that they may be potential carcinogens (41, 42). Aromatic cyanides related to those from cabbage have been shown to be mutagens and are metabolized to hydrogen cyanide and potentially mutagenic aldehydes (43).

Concentrations of natural pesticides in plants are usually measured in parts per thousands or million (16-23) rather than parts per billion, the usual concentration of synthetic pesticide residues or of water pollutants (1, 24). We estimate that humans ingest roughly 5000 to 10,000 different natural pesticides and their breakdown products (16-23). For example, Table 1 shows 49 natural pesticides (and metabolites) that are ingested when cabbage is eaten, and indicates how few have been tested for carcinogenicity or clastogenicity. Lima beans contain a completely different array of 23 natural toxins that, in stressed plants, range in concentration from 0.2 to 33 parts per thousand fresh weight; none appears to have been tested yet for carcinogenicity or teratogenicity (19). Many Leguminosae contain canavanine, a toxin arginine analog that, after being eaten by animals, is incorporated into protein in place of arginine. Feeding alfalfa sprouts (1.5% canavanine dry weight) or canavanine to monkeys causes a lupus erythematosus-like syndrome (44). Lupus in humans is characterized by a defect in the immune system that is associated with autoimmunity, anti-nuclear antibodies, chromosome breaks, and various types of pathology. The toxicity of nonfood plants is well known: plants are among the most commonly ingested poisonous substances for children under 5 years.

Surprisingly few plant toxins have been tested for carcinogenicity (10-13, 45). Among 1052 chemicals tested in at least one species in chronic cancer tests, only 52 are naturally occurring plant pesticides (10-13). Among these, about half (27/52) are carcinogenic.// Even though only a tiny proportion of the plant toxins in our diet have been tested so far, the 27 natural pesticides that are rodent carcinogens are present in the following foods: anise, apple, apricot, banana, basil, broccoli, brussels sprouts, cabbage, cantaloupe, caraway, carrot, cauliflower, celery, cherries, cinnamon, cloves, cocoa, coffee, collard greens, comfrey herb tea, currants, dill, eggplant, endive, fennel, grapefruit juice, grapes, guava, honey, honeydew melon, horseradish, kale, lentils, lettuce, mango, mushrooms, mustard, nutmeg, orange juice, parsley, parsnip, peach, pear, peas, black pepper, pineapple, plum, potato, radish, raspberries, rosemary, sesame seeds, tarragon, tea, tomato, and turnip. Thus, it is probable that almost every fruit and vegetable in the supermarket contains natural plant pesticides that are rodent carcinogens. The levels of these 27 rodent carcinogens in the above plants are commonly thousands of times higher than the levels of synthetic pesticides. Table 2 shows a variety of natural pesticides that are rodent carcinogens occurring in the parts-per-million range in plant foods.

The catechol-type phenolics, such as tannins, and caffeic acid and its esters (chlorogenic and neochlorogenic acids), are more widespread in plant species than other natural pesticides (e.g., Tables 1 and 2). It may be that these phenolics have an antimicrobial role analogous to the

//The list of 52 natural plant pesticides includes 7 toxins from edible mushrooms because mushrooms are commonly considered a plant food. Fungal toxins are not included but are given below.

Plant pesticides. Carcinogens: acetaldehyde methylformylhydrazone, allyl isothiocyanate, arecoline hydrochloride, benzaldehyde, benzyl acetate, caffeic acid, catechol, clivorine, cycasin/methylazoxymethanol acetate mixture. estragole, ethyl acrylate, glutamyl *p*-hydrazinobenzoic acid, *p*-hydrazinobenzoic acid, lasiocarpine, *N*-methyl-*N*-formylhydrazine, D-limonene, a-methylbenzyl alcohol, methylhydrazine, 8-methoxypsoralen, monocrotaline, pentanal methylformalhydrazone, petasitenine, reserpine, safrole, senkirkine, sesamol, and symphytine. [Cycasin as well as its metabolite methylazoxymethanol are positive in numerous tests (45) that do not meet the inclusion criteria of the database.] 5- and 8-Methoxypsoralen and psoralen are light-activated mutagens (17, 45, 46). 8-Methoxypsoralen is positive in a National Toxicology Program gavage study (without light) and is in the database (47). 5-Methoxypsoralen and psoralen have only been tested in a skin painting study (with light) and are positive (46); they are not in our database, because the route of administration would not result in whole body exposure. Noncarcinogens: atropine, benzyl alcohol. biphenyl, caffeine, carvone, deserpidine disodium glycyrrhizinate, emetine dihydrochloride, ephedrine sulfate, eucalyptol, eugenol, *b*-*N*-[g-L(+)-glutamyl]-4-hydroxymethylphenylhydrazine, isosafrole, kaempferol, DL-menthol, nicotine, norharman, pilocarpine, piperidine, rotenone, rutin sulfate, sodium benzoate, and vinblastine. Uncertain: *trans*-anethole and quercetin.

Fungal toxins. Among 16 fungal toxins tested for carcinogenicity 11 were positive. Carcinogens: aflatoxin, 5-azacytidine, azaserine citrinin, griseofulvin, luteoskyrin, mitomycin C, ochratoxin A, sterigmatocystin, streptozotocin, and zearalenone. Noncarcinogens: erythromycin stearate, fusarenon X, oxytetracycline hydrochloride, patulin, and penicillin VK.

Table 2. Some natural pesticide carcinogens in food

Rodent carcinogen	Conc., ppm	Plant food
5-/8-Methoxypsoralen	14	Parsley
	32	Parsnip, cooked
	0.8	Celery
	6.2	Celery, new cultivar
	25	Celery, stressed
p-Hydrazinobenzoate	11	Mushrooms
Glutamyl p-hydrazinobenzoate	42	Mushrooms
Sinigrin* (allyl isothiocyanate)	35-590	Cabbage
	250-788	Collard greens
	12-66	Cauliflower
	110-1,560	Brussels sprouts
	16,000-72,000	Mustard (brown)
	4,500	Horseradish
D-Limonene	31	Orange juice
	40	Mango
	8,000	Pepper, black
Estragole	3,800	Basil
	3,000	Fennel
Safrole	3,000	Nutmeg
	10,000	Mace
	100	Pepper, black
Ethyl acrylate	0.07	Pineapple
Sesamol	75	Sesame seeds (heated oil)
α-Methylbenzyl alcohol	1.3	Cocoa
Benzyl acetate	82	Basil
	230	Jasmine tea
	15	Honey
Catechol	100	Coffee (roasted beans)
Caffeic acid	50-200	Apple, carrot, celery, cherry, eggplant, endive, grapes, lettuce, pear, plum,potato
	>1,000	Absinthe, anise, basil, caraway, dill, marjoram, rosemary, sage, savory, tarragon, thyme
	1,800	Coffee (roasted beans)
Chlorogenic acid† (caffeic acid)	50-500	Apricot, cherry, peach, plum
	21,600	Coffee (roasted beans)
Neochlorogenic acid† (caffeic acid)	50-500	Apple, apricot, broccoli, brussels sprouts, cabbage, cherry, kale, peach, pear, plum
	11,600	Coffee (roasted beans)

Carcinogen tests are referenced in refs. 10-13 and the following: 5-methoxypsoralen (light-activated) and 8-methoxypsoralen (46, 47) (psoralen, which is carcinogenic by skin painting, and many other mutagenic psoralen derivatives are also present in parsley and celery); *p*-hydrazinobenzoate and glutamyl *p*-hydrazinobenzoate (48, 49); allyl isothiocyanate (31, 32); D-limonene (50); estragole and safrole (45, 51); ethyl acrylate and benzyl acetate (52); α-methylbenzyl alcohol (53); caffeic acid (37); sesamol (37); catechol (37). Concentration references are as follows: 5- and 8-methoxypsoralen (17, 55-59); *p*-hydrazinobenzoates (in commercial mushrooms) (48, 49); sinigrin (38-40, 60); D-limonene (61-63); estragole and safrole (64-67); ethyl acrylate (68); benzyl acetate (69-71), α-methylbenzyl alcohol (23); caffeic acid, chlorogenic acid, and neochlorogenic acid (72-80) [in coffee (81)]; catechol (83, 84); sesamol (85). For mutagenicity and clastogenicity references, see text.
*Sinigrin is a cocarcinogen (33) and is metabolized to the rodent carcinogen allyl isothiocyanate, although no adequate test has been done on sinigrin itself. The proportion converted to allyl isothiocyanate or to allyl cyanide depends on food preparation (38-40).
†Chlorogenic and neochlorogenic acid are metabolized to the carcinogens caffeic acid and catechol (a metabolite of quinic acid) but have not been tested for carcinogenicity themselves. The clastogenicity and mutagenicity of these compounds are referenced in Table 1.

respiratory burst of oxygen radicals from mammalian phagocytic cells. The phenolics oxidize when a plant is wounded, yielding a burst of mutagenic oxygen radicals (e.g., the browning when an apple is cut).

Caution is necessary in interpreting the implications of the occurrence in the diet of natural pesticides that are rodent carcinogens. It is not argued here that these dietary exposures are necessarily of much relevance to human cancer. Indeed, a diet rich in fruit and vegetables is associated with lower cancer rates (86, 87). This may be because anticarcinogenic vitamins and antioxidants come from plants (86, 87). What is important in our analysis is that exposures to natural rodent carcinogens may cast doubt on the relevance of far lower levels of exposures to synthetic rodent carcinogens.

Residues of Synthetic Pesticides. A National Research Council report (88) has discussed the regulation of of synthetic pesticides that are rodent carcinogens, but ignored natural pesticides. The U.S. Food and Drug Administration (FDA) has assayed food for 200 chemicals including the

synthetic pesticide residues thought to be of greatest importance and the residues of some industrial chemicals such as polychlorinated biphenyls (PCBs) (24). The FDA found residues for 105 of these chemicals: the U.S. intake of the sum of these 105 chemicals averages about 0.09 mg per person per day, which we compare to 1.5 g of natural pesticides (i.e., 99.99% natural).** Other analyses of synthetic pesticide residues are similar (90). About half (0.04 mg) of this daily intake of synthetic pesticides is composed of four chemicals (24) that were not carcinogenic in rodent tests: ethylhexyl diphenyl phosphate, chlorpropham, malathion, and dicloran (10, 89). Thus, the intake of rodent carcinogens from synthetic residues is only about 0.05 mg a day (averaging about 0.06 ppm in plant food) even if one assumes that all the other residues are carcinogenic in rodents (which is unlikely).

Cooking Food. The cooking of food is also a major dietary source of potential rodent carcinogens. Cooking produces about 2 g (per person per day) of mostly untested burnt material that contains many rodent carcinogens—e.g., polycyclic hydrocarbons (81, 91), heterocyclic amines (92, 93), furfural (22, 23), nitrosamines and nitroaromatics (1, 94)—as well as a plethora of mutagens (91-95). Thus, the number and amounts of carcinogenic (or total) synthetic pesticide residues appear to be minimal compared to the background of naturally occurring chemicals in the diet. Roasted coffee, for example, is known to contain 826 volatile chemicals (22); 21 have been tested chronically and 16 are rodent carcinogens (10-13); caffeic acid, a nonvolatile rodent carcinogen, is also present (Table 2). A typical cup of coffee contains at least 10 mg (40 ppm) of rodent carcinogens (mostly caffeic acid, catechol, furfural, hydroquinone and hydrogen peroxide) (Table 2). The evidence on coffee and human health has been recently reviewed, and the evidence to date is insufficient to show that coffee is a risk factor for cancer in humans (81, 86). The same caution about the implications for humans of rodent carcinogens in the diet that were discussed above for nature's pesticides apply to coffee and the products of cooked food.

Clastogenicity and Mutagenicity Studies. Results from *in vitro* studies also indicate that the natural world should not be ignored and that positive results are commonly observed in high-dose protocols. Ishidate *et al.* (26) reviewed experiments on the clastogenicity (ability to break chromosomes) of 951 chemicals in mammalian cell cultures. Of these 951 chemicals, we identified 72 as natural plant pesticides, and 35 (48%) were positive for clastogenicity in at least one test. This is similar to the results for the remaining chemicals, of which 467/879 (53%) were positive in at least one test.

Of particular interest are the levels at which some of the carcinogenic plant toxins in Table 2 were clastogenic (26). Allyl isothiocyanate was clastogenic at a concentration of 0.0005 ppm, which is about 200,000 times less than the concentration of sinigrin, its glucosinolate, in cabbage. Allyl isothiocyanate was among the most potent chemicals in the compendium (26) and is also effective at unusually low levels in transforming (96) and mutating (30) animal cells. (See also the discussion of cancer tests in Table 1.) Safrole was clastogenic at a concentration of about 100 ppm, which is 30 times less than the concentration in nutmeg and roughly equal to the concentration in black pepper. The rodent carcinogens safrole and estragole, and a number of other related dietary natural pesticides that have not been tested in animal cancer tests, have been shown to produce DNA adducts in mice (97). Caffeic acid was clastogenic at a concentration of 260 and 500 ppm, which is less than its concentration in roasted coffee beans and close to its concentration in apples, lettuce, endive, and potato skin. Chlorogenic acid, a precursor of caffeic acid, was clastogenic at a concentration of 150 ppm, which is 100 times less than its concentration in roasted coffee beans and similar to its concentration in apples, pears, plums, peaches, cherries, and apricots. Chlorogenic acid and caffeic acid are also mutagens (Table 1). Coffee is genotoxic to mammalian cells (98). Plant phenolics such as caffeic acid, chlorogenic acid, and tannins (esters of gallic acid) have been reviewed for their mutagenicity and antimutagenicity, clastogenicity, and carcinogenicity (99).

**Figures here are based on men aged 25-30 in 1982-1984. Cancer test results are in refs. 10-13. The negative test on 2-ethylhexyl diphenyl phosphate is in ref. 89. The latest FDA figures on actual exposures do not include every known synthetic pesticide, and diets vary. Nevertheless, 0.05 mg of possibly carcinogenic pesticide residues consumed in a day seems to be a reasonable rough estimate.

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Nature's chemicals and synthetic chemicals: Comparative toxicology*

(carcinogens/mutagens/teratogens/clastogens/dioxin)

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ABSTRACT **The toxicology of synthetic chemicals is compared to that of natural chemicals, which represent the vast bulk of the chemicals to which humans are exposed. It is argued that animals have a broad array of inducible general defenses to combat the changing array of toxic chemicals in plant food (nature's pesticides) and that these defenses are effective against both natural and synthetic toxins. Synthetic toxins such as dioxin are compared to natural chemicals such as indole carbinol (in broccoli) and ethanol. Trade-offs between synthetic and natural pesticides are discussed. The finding that in high-dose tests, a high proportion of both natural and synthetic chemicals are carcinogens, mutagens, teratogens, and clastogens (30-50% for each group) undermines current regulatory efforts to protect public health from synthetic chemicals based on these tests.**

The Toxicology of Synthetic and Natural Toxins Is Similar

It is often assumed that, because plants are part of human evolutionary history whereas synthetic chemicals are recent, the mechanisms that animals have evolved to cope with the toxicity of natural chemicals will fail to protect us against synthetic chemicals (1, 64).¶ We find this assumption flawed for several reasons.

(i) Defenses that animals have evolved are mostly of a general type, as might be expected, since the number of natural chemicals that might have toxic effects is so large. General defenses offer protection not only against natural but also against synthetic chemicals, making humans well buffered against toxins (2-6). These defenses include the following. *(a)* The continuous shedding of cells exposed to toxins: the surface layers of the mouth, esophagus, stomach, intestine, colon, skin, and lungs are discarded every few days. *(b)* The induction of a wide variety of general detoxifying mechanisms, such as antioxidant defenses (7, 8) or the glutathione transferases for detoxifying alkylating agents (9): human cells that are exposed to small doses of an oxidant, such as radiation or hydrogen peroxide, induce antioxidant defenses and become more resistant to higher doses (10-14). These defenses can be induced both by synthetic oxidants (e.g., the herbicide paraquat) and by natural oxidants and are effective against both. *(c)* The active excretion of planar hydrophobic molecules (natural or synthetic) out of liver and intestinal cells (15). *(d)* DNA repair: this is effective against DNA adducts formed from both synthetic and natural chemicals and is inducible in response to DNA damage (16). *(e)* Animals' olfactory and gustatory perception of bitter, acrid, astringent, and pungent chemicals: these defenses warn against a wide range of toxins and could possibly be more effective in warning against some natural toxins that have been important in food toxicity during evolution, than against some synthetic toxins. However, it seems likely that these stimuli are also general defenses and are monitoring particular structures correlated with toxicity; some synthetic toxic compounds are also pungent, acrid, or astringent. Even though mustard, pepper, garlic, onions, etc. have some these attributes, humans often ignore the warnings.

That defenses are usually general, rather than specific for each chemical, makes good evolutionary sense. The reason that predators of plants evolved general defenses against toxins is presumably to be prepared to counter a diverse and ever-changing array of plant toxins in an evolving world, if a herbivore had defenses against only a set of specific toxins it would be at a great disadvantage in obtaining new foods when favored foods became scarce or evolved new toxins.

(ii) Various natural toxins, some of which have been present throughout vertebrate evolutionary history, nevertheless cause cancer in vertebrates. Mold aflatoxins, for example, have been shown to cause cancer in trout, rats, mice, monkeys, and possibly in humans (2,17). Eleven mold toxins have been reported to be carcinogenic (6), and 19 mold toxins have been shown to be clastogenic (18). Many of the common elements are carcinogenic (e.g., salts of lead, cadmium, beryllium, nickel, chromium, selenium, and arsenic) or clastogenic (18) at high doses, despite their presence throughout evolution. Selenium and chromium are essential trace elements in animal nutrition.

Furthermore, epidemiological studies from various parts of the world show that certain natural chemicals in food may be carcinogenic risks to humans: the chewing of betel nuts with tobacco around the world has been correlated with oral cancer (17,19). The phorbol esters present in the Euphorbiaceae, some of which are used as folk remedies or herb teas, are potent mitogens and are thought to be a cause of nasopharyngeal cancer in China and esophageal cancer in Curacao (20, 21). Pyrrolizidine toxins are mutagens that are found in comfrey tea, various herbal medicines, and some foods; they are hepatocarcinogens in rats and may cause liver cirrhosis and other pathological states in humans (19).

Plants have been evolving and refining their chemical weapons for at least 500 million years and incur large fitness costs in producing these chemicals. If these chemicals were not effective in deterring predators, plants would not have been naturally selected to produce them.

(iii) Humans have not had time to evolve into a "toxic harmony" with all of the plants in their diet. Indeed, very few of the plants that humans eat would have been present in an African hunter-gatherer's diet. The human diet has changed drastically in the last few thousand years, and most humans are eating many recently introduced plants that their ancestors did not—e.g., coffee, cocoa, tea, potatoes, tomatoes, corn, avocados, mangoes, olives, and kiwi fruit. In addition, cruciferous vegetables such as cabbage, broccoli, kale, cauliflower, and mustard were used in ancient times "primarily for medicinal purposes" and were spread as foods across Europe only in the Middle Ages (22, 23). Natural selection works far too slowly for humans to have evolved specific resistance to the food toxins in these newly introduced plants.

(iv) Poisoning from plant toxins in the milk of foraging animals was quite common in previous centuries. Cow or goat milk and other ingested dairy products were contaminated by the natural toxins from plants that were eaten by foraging animals in nonindustrial, agricultural societies, because toxins that are absorbed through the animal's gut are often

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secreted in the milk. Since the plants foraged by cows vary from place to place and are usually inedible for human consumption, the plant toxins that are secreted in the milk are, in general, not toxins to which humans could have easily adapted. Abraham Lincoln's mother, for example, died from drinking cow's milk that had been contaminated with toxins from the snakeroot plant (24). Foraging cows can eat bracken fern, which contains a known carcinogen; the milk from cows eating bracken fern is carcinogenic to rats (19). When cows and goats forage on lupine, their offspring may have teratogenic abnormalities, such as "crooked calf" syndrome caused by the anagyrine in lupine (25-27). Such significant amounts of these teratogens can be transferred to the animals' milk that drinking the milk during pregnancy is a teratogenic risk for humans (25-27): in one rural California family, a baby boy, a litter of puppies, and goat kids all had a "crooked" bone birth defect. Both the pregnant woman and the pregnant dog had been drinking milk obtained from the family goats, which had been foraging on lupine, the main forage in winter (25-27).

(v) Anticarcinogenic chemicals in the diet may help to protect humans equally well against synthetic and natural carcinogens. Although plants contain anticarcinogenic chemicals that may protect against carcinogens (28, 29, 64), these anticarcinogens (e.g., plant antioxidants) do not distinguish whether carcinogens are synthetic or natural in origin.

(vi) It has been argued that synergism between synthetic carcinogens could multiply hazards; however, this is also true of natural chemicals, which are by far the major source of chemicals in the diet.

(vii) DDT bioconcentrates in the food chain due to its unusual lipophilicity; however, natural toxins can also bioconcentrate. DDT ["dichlorodiphenyltrichloroethane," 1,1,1-trichloro-2,2-bis(*p*-chlorophenyl)ethane] is often viewed as the typically dangerous synthetic pesticide because it persists for years; it was representative of a class of chlorinated pesticides. Natural pesticides, however, also bioconcentrate if lipophilic: the teratogens solanine (and its aglycone solanidine) and chaconine, for example, are found in the tissues of potato eaters (30-32). Although DDT was unusual with respect to bioconcentration, it was remarkably nontoxic to mammals, saved millions of lives, and has not been shown to cause harm to humans (33). To a large extent DDT, the first major synthetic insecticide, replaced lead arsenate, a major carcinogenic pesticide used before the modern era; lead arsenate is even more persistent than DDT. When the undesirable bioconcentration and persistence of DDT and its lethal effects on some birds were recognized it was prudently phased out, and less persistent chemicals were developed to replace it. Examples are the synthetic pyrethroids that disrupt the same sodium channel in insects as DDT (34), are degraded rapidly in the environment, and can often be used at a concentration as low as a few grams per acre.

(viii) Natural toxins can have the same mechanisms of toxicity as synthetic toxins: the case of dioxin. Cabbage and broccoli contain a chemical whose breakdown products bind to the body's aromatic hydrocarbon (Ah) receptor, induce the defense enzymes under the control of the receptors, and possibly cause mitogenesis—just as does dioxin [2,3,7,8-tetrachlorodibenzo-*p*-dioxin (TCDD)], one of the most feared industrial contaminants. TCDD is of great public concern because it is carcinogenic and teratogenic in rodents at extremely low doses. The doses humans ingest are, however, far lower than the lowest doses that have been shown to cause cancer and reproductive damage in rodents.

TCDD exerts many or all of its harmful effects in mammalian cells through binding to the Ah receptor (35). A wide variety of natural substances also bind to the Ah receptor [e.g., tryptophan oxidation products (36)] and insofar as they have been examined, they have similar properties to TCDD. A cooked steak, for example, contains polycyclic hydrocarbons that bind to the Ah receptor and mimic TCDD. In addition, a variety of flavones and other plant substances in the diet, such as indole carbinol (IC), also bind to the Ah receptor. IC is the main breakdown compound of glucobrassicin, a glucosinolate that is present in large amounts in vegetables of the *Brassica* genus, including broccoli (about 25 mg per 100-g portion) (62) Brussels sprouts (125 mg per 100 g) (62), and cabbage (25 mg per 100 g) (23). When tissues of these vegetables are lacerated, as occurs during chewing, they release an enzyme that breaks down the glucobrassicin. The enzyme is quite heat stable, and cooked vegetables yield most of the indole compounds that raw vegetables do (37). Therefore, we assume for the following calculation that 20% of glucobrassicin is converted to IC on eating. At the pH of the stomach, IC makes dimers and trimers that induce the same set of detoxifying enzymes as TCDD (37-39). IC, like TCDD, protects against carcinogenesis when given *before* aflatoxin or other carcinogens (39-41). However, when given *after* aflatoxin or other carcinogens, IC, like TCDD, stimulates carcinogenesis (38). This stimulation of carcinogenesis has also been shown for cabbage itself (42). These IC derivatives appear to be much more of a potential hazard than TCDD if binding to the Ah receptor is critical for toxic effects. The Environmental Protection Agency's human "reference dose" (formerly "acceptable dose limit") of TCDD is 6 fg per kg per day. This should be compared with 5 mg of IC per 100 of broccoli or cabbage (6). Although the affinity of one major indole dimer in binding to Ah receptors is less than that of TCDD by a factor of about 8000 (L. F. Bjeldanes and C. A. Bradfield, personal communication), the effective dose to the Ah receptor from a helping of broccoli would be about 1500 times higher than that of TCDD, taking into account an extra factor of 1000 for the very long lifetime of TCDD in the body (several years) and assuming that the lifetime of the hydrophobic indole dimers is as short as 1 day. Another IC dimer has recently been shown to bind to the Ah receptor with about the same affinity as TCDD (L. Bjeldanes, personal communication). However, it is not clear whether at the low doses of human exposure either is hazardous; they may even be protective. It seems likely that many more of these natural "dioxin simulators" will be discovered in the future.

If TCDD is compared with ethanol it seems of minor interest as a teratogen or carcinogen. Alcoholic beverages are the most important known human chemical teratogens (43). In contrast, there is no persuasive evidence that TCDD is either carcinogenic or teratogenic in humans, although it is both at near-toxic doses in rodents. If one compares the teratogenic potential of TCDD to that of alcohol for causing birth defects (after adjusting for their respective potency as determined in rodent tests), then a daily consumption of the Environmental Protection Agency's reference dose of TCDD (6 fg per kg) would be equivalent in teratogenic potential to a daily consumption of alcohol from 1/3,000,000th of a beer. That is equivalent to drinking a single beer (15 g of ethanol) over a period of 8000 years.

Alcoholic beverages in humans are a risk factor for cancer (17) as well as birth defects. A comparison of the carcinogenic potential for rodents of TCDD with that of alcohol (adjusting for the potency in rodents) (2) shows that ingesting the TCDD reference dose of 6 fg per kg per day is equivalent to ingesting one beer every 345 years. Since the average consumption of alcohol in the United States is equivalent to more than one beer per person per day, and since five drinks a day are a carcinogenic risk in humans, the experimental evidence does not of itself seem to justify the great concern over TCDD at levels in the range of the reference dose.

Trade-Offs Between Natural and Synthetic Pesticides

Since no plot of land is immune to attack by insects, plants need chemical defenses, either natural or synthetic, in order to survive pest attack. "It has been suggested that one consequence of crop plant domestication is the deliberate or inadvertent selection for reduced levels of secondary compounds that are distasteful or toxic. Insofar as many of these chemicals are involved in the defense of plants against their enemi the reduction due to artificial selection in these defenses may account least in part for the increased susceptibility of crop plants to herbivores

pathogens. . . ." (44). Therefore, there is a trade-off between nature's pesticides and synthetic pesticides.

Cultivated plant foods commonly contain on average fewer natural toxins than do their wild counterparts. For example, the wild potato *Solanum acaule*, the progenitor of cultivated strains of potato, has a glycoalkaloid content about 3 times that of cultivated strains and is more toxic (45, 46). The leaves of the wild cabbage *Brassica oleracea* (the progenitor of cabbage, broccoli, and cauliflower) contain about twice as many glucosinolates as cultivated cabbage (47). The wild bean *Phaseolus lunatus* contains about 3 times as many cyanogenic glucosides as does the cultivated bean (48). Similar reductions in toxicity through agriculture have been reported in lettuce, lima bean, mango, and cassava (49).

One consequence of disproportionate concern about synthetic pesticide residues is that plant breeders are developing plants that are more insect-resistant but that are also higher in natural toxins. Two recent cases illustrate the potential hazards of this approach to pest control. *(i)* When a major grower introduced a new variety of highly insect-resistant celery into commerce, a flurry of complaints were made to the Centers of Disease Control from all over the country because people who handled the celery developed rashes and burns when they were subsequently exposed to sunlight. Some detective work found that the pest-resistant celery contained 6200 ppb of carcinogenic (and mutagenic) psoralens instead of the 800 ppb present in normal celery (6, 50-52). It is not known whether other natural pesticides in the celery were increased as well. The celery is still on the market. *(ii)* A new potato cultivar, developed at a cost of millions of dollars, had to be withdrawn from the market because of its acute toxicity to humans—a consequence of higher levels of two natural toxins, solanine and chaconine. Solanine and chaconine inhibit cholinesterase, thereby blocking nerve transmission, and are known rodent teratogens. They were widely introduced into the world diet about 400 years ago with the dissemination of the potato from the Andes. Total toxins are present in normal potatoes at a level of 15 mg per 200-g potato (75 ppm), which is less than a 10-fold safety margin from the measurably toxic, daily dose level for humans (45). Neither solanine nor chaconine has been tested for carcinogenicity. In contrast, the cholinesterase inhibitor malathion, the main synthetic organophosphate pesticide residue in our diet (0.006 mg per day), has been tested and is not a carcinogen in rats or mice. Common cultivars of plants differ widely in the level of particular natural toxins (6), and other factors in the plant also play a part in pest resistance. Breeding or genetic engineering can be used to increase or decrease specific chemicals or other factors.

Certain cultivated crops have become popular in developing countries because they thrive without costly synthetic pesticides. However, the trade-offs of cultivating some of these naturally pest-resistant crops are that they are highly toxic and require extensive processing to detoxify them. For example, cassava root, a major food crop in Africa and South America, is quite resistant to pests and disease; however,it contains cyanide at such high levels that only a laborious process of washing, grinding, fermenting, and heating can make it edible; ataxia due to chronic cyanide poisoning is endemic in many of the cassava-eating areas of Africa (53). In one part of India, the pest-resistant grain *Lathyrus sativus* is cultivated to make some types of dahl. Its seeds contain the neurotoxin ß-N-oxalylaminoalanine, which causes a crippling nervous system disorder, neurolathyrism (54).

There is a tendency for nonscientists to think of *chemicals* as being only synthetic and to characterize synthetic chemicals as toxic, as if every natural chemical were not also toxic at some dose. Even a recent National Research Council report (55) states: "Advances in classical plant breeding. . . offer some promise for nonchemical pest control in the future. Nonchemical approaches will be encouraged by tolerance revocations. . . ." The report was concerned with pesticide residues but ignored natural pesticides. Tomatine, one of the natural toxins in tomatoes, is a recent chemical too, since it was introduced to the world diet from Peru 400 years ago. Neither tomatine nor its aglycone, tomatidine, an antifungal steroid-like molecule, has been tested in rodent cancer bioassays. Tomatine is present at 36 mg per 100-g tomato (360 ppm), a concentration that is much closer to the acutely toxic level in humans than are synthetic pesticide residues (45).

As an alternative to synthetic pesticides, it is legal for "organic farmers" to use the natural pesticides from one plant species against pests that attack a different plant species, e.g., rotenone (which Indians used to poison fish) or the pyrethrins from chrysanthemum plants. These naturally derived pesticides have not been tested as extensively for carcinogenicity (rotenone is negative, however), mutagenicity, or teratogenicity as have synthetic pesticides; therefore, their safety compared to synthetically derived pesticides should not be prematurely assumed.

Synthetic pesticides have markedly lowered the cost of plant food, thus increasing consumption. Eating more fruits and vegetables and less fat may be the best way to lower risks of cancer and heart disease, other than giving up smoking (35, 56, 57)

"Toxic Chemicals" and Human Risk

Positive results are remarkably common in high-dose screening tests for carcinogens, clastogens (agents that break chromosomes), teratogens, and mutagens. About half of the chemicals tested, whether natural or synthetic, are carcinogens in chronic, high-dose rodent tests (5, 6) and about half are clastogens in tissue culture tests (18). A high proportion of positives is also reported for rodent teratogenicity tests: 38% of the 2800 chemicals tested in laboratory animals "have been teratogenic" in the standard, high-dose protocol (58). It is therefore reasonable to assume that a sizeable percentage of both synthetic and natural chemicals will be reproductive toxins at high doses. Mutagens may also be common: of the 340 chemicals tested for carcinogenicity in both rats and mice and for mutagenicity in *Salmonella* (ref. 59; L.S.G., unpublished work), 46% were mutagens, and mutagens were nearly twice as likely to be carcinogenic than were nonmutagens. Of these 340 chemicals, 70% were either mutagens or carcinogens or both. How much this high frequency of positive results is due to bias in selecting chemicals is not known (5). Even if selection bias doubled the percentage of positives, which we think is unlikely (5), the high proportion of positives would still mean that almost everything natural we eat contains carcinogens, mutagens, teratogens, and clastogens (6). Thus, testing a random group of natural pesticides and pyrolysis products from cooking should be a high priority for these various tests so that an adequate comparison can be made to synthetic toxins.

Dozens of mammalian metabolites are commonly produced from any reasonably complex molecule. Therefore, even nonmutagenic, nonclastogenic, noncarcinogenic, and nonteratogenic chemicals, whether synthetic or natural, are likely to produce some carcinogenic, clastogenic, teratogenic, and mutagenic mammalian metabolites.

Several chemicals that have been shown to be carcinogens at high doses in rodents have also been shown to be anticarcinogens in other animal models at lower doses—e.g., limonene, caffeic acid, TCDD, and IC (28, 29). Therefore, the dose and context of a chemical exposure may be critical.

The first rule of toxicology is that all chemicals are "toxic chemicals;" it is the dose that makes the poison. High-dose tests are relevant for some occupational or medicinal exposures that can be at high doses (2, 60). With mutagens there is some theoretical justification for thinking that low doses may have an effect, although the complexities of inducible protection systems may well produce a dose-response threshold, or even protective effects at very low doses. The high endogenous DNA damage rate is also relevant (5). In any case, there should be a threshold of attention for hypothetical risks that are low compared to background risks, otherwise resources are diverted from more important risks. The arguments in this and the preceding papers (5, 6) undermine many assumptions of current regulatory policy and necessitate a rethinking of policy designed to reduce

human cancer. Minimizing pollution is a separate issue and is clearly desirable for reasons other than effects on public health.

It is by no means clear that many significant risk factors for human cancer will be single chemicals that will be discovered by screening assays. Dietary imbalances are likely to be a major contributor to human cancer (43, 56, 57) and understanding these should be, but is not, a major priority of research. Understanding why caloric restriction dramatically lowers cancer and mitogenesis rates and extends life-span in experimental animals (61, 62) should also be a major research priority. More studies on mechanisms of carcinogenesis are also a high priority.

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Abbreviations: DDT, 1,1,1,-trichloro-2,2-bis(*p*-chlorophenyl)ethne ("dichlorodiphenyltrichloroethane"); TCDD, 2,3,7,8-tetrachlorodibenzo-*p*-dioxin; IC, indole-3-carbinol; Ah receptor, aromatic hydrocarbon receptor.

*This is paper no. 3 of a series. Paper no. 2 is ref. 6.

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¶"For the first time in the history of the world, every human being is now subjected to contact with dangerous chemicals, from the moment of conception until death." Rachel Carson (1962) *Silent Spring* (Houghton Miffiin, Boston), p. 15.

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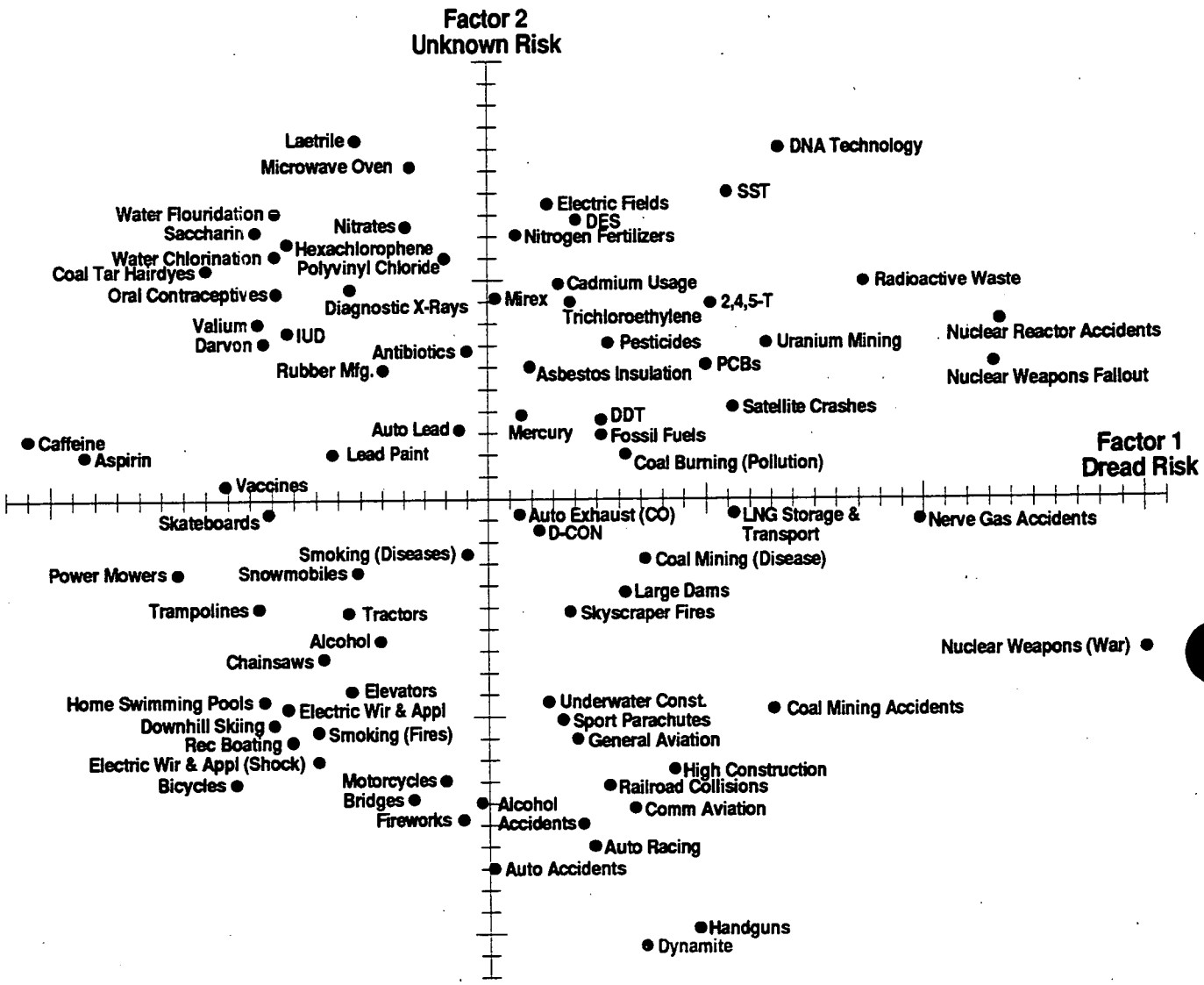
Factor 2
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Factor 1
Dread Risk
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Microwave Oven
Water Flouridation
Saccharin
Nitrates
Hexachlorophene
Water Chlorination
Polyvinyl Chloride
Coal Tar Hairdyes
Oral Contraceptives
Diagnostic X-Rays
Valium
Darvon
IUD
Antibiotics
Rubber Mfg.
Caffeine
Aspirin
Auto Lead
Lead Paint
Vaccines
Skateboards
Smoking (Diseases)
Power Mowers
Snowmobiles
Trampolines
Tractors
Alcohol
Chainsaws
Elevators
Home Swimming Pools
Electric Wir & Appl
Downhill Skiing
Smoking (Fires)
Rec Boating
Electric Wir & Appl (Shock)
Bicycles
Motorcycles
Bridges
Fireworks
Alcohol
Accidents
Auto Accidents
DNA Technology
SST
Electric Fields
DES
Nitrogen Fertilizers
Cadmium Usage
Radioactive Waste
Mirex
Trichloroethylene
2,4,5-T
Nuclear Reactor Accidents
Pesticides
Uranium Mining
Asbestos Insulation
PCBs
Nuclear Weapons Fallout
Satellite Crashes
DDT
Mercury
Fossil Fuels
Coal Burning (Pollution)
Auto Exhaust (CO)
D-CON
LNG Storage &
Transport
Nerve Gas Accidents
Coal Mining (Disease)
Large Dams
Skyscraper Fires
Nuclear Weapons (War)
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Sport Parachutes
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Comm Aviation
Auto Racing
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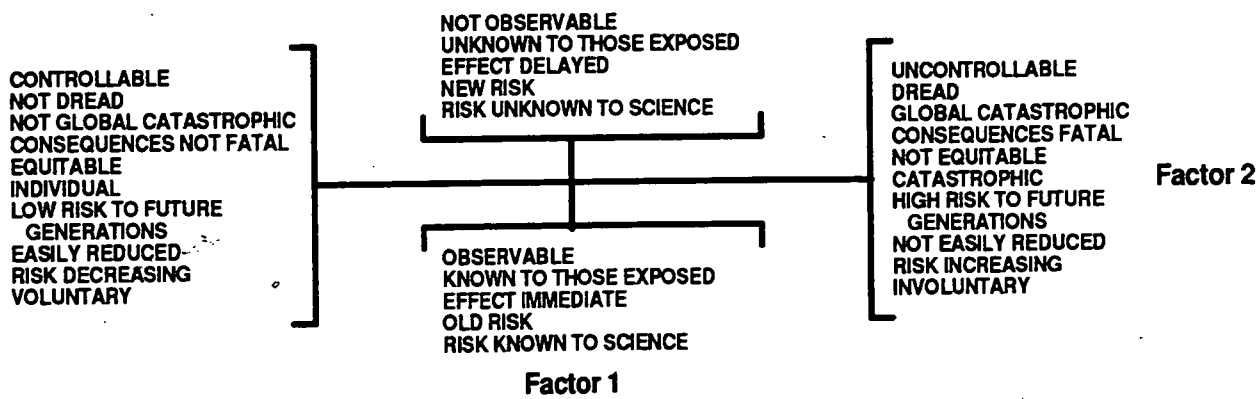
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HIGH RISK TO FUTURE
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Glossary of Terms

ALARA	As low as reasonably achievable
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
FDA	Food and Drug Administration
MCL	Maximum contaminant level
MCLG	Maximum contaminant level goal
NCP	National Oil and Hazardous Substances Pollution Contingency Plan
OSHA	Occupational Safety and Health Administration
pCi	Picocurie

Suggested Readings

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Test Questions

1. (True or False) Within the general approach followed by FDA in the management of carcinogenic food additives, a "de minimis" risk would describe a lifetime risk of cancer of less than one in a million.
2. (True or False) In developing the PEL for a chemical, OSHA considers only the health effects of potential worker exposure.
3. When dealing with potential exposure to radiation, what is "ALARA?"
4. (True or False) The media will invariably give a great deal of attention to a few deaths from unusual or unexpected risks, while largely ignoring such huge risks as alcohol abuse, lifestyle-related heart disease and failure to use automobile seatbelts.
5. (True or False) Large corporations can be trusted to immediately publicize any research hints of previously unknown hazards involving their products and to take prompt action to protect their employees, customers, and the general public.
6. (True or False) Government at any level is adept at anticipating risks, trying to prevent them, and acting to limit their damage.
7. How do the factors that influence public perceptions of risk differ from the factors that influence experts' assessments?
8. Is one perspective, technical or public, more legitimate and more useful than the other? Why or why not?
9. How can an understanding of risk perception improve risk communication?
10. What is social amplification of risk and why is it important?
11. What event precipitated the controversy which led to the coining of the term "environmental racism?"
12. Has it been shown that minority communities bear a disparate impact of the risks posed by environmental hazards?
13. Isn't the siting of hazardous waste producing and disposal primarily (or only) economic?
14. How does one define culture?
15. How does one define paradigm?
16. Describe the shift from one paradigm to another.
17. If one is unable to show intent to adversely affect a minority community, what legal options remain to an effected community?
18. Under what conditions can a minority community successfully block public decisions effecting them?
19. In working with local communities, what approaches have been shown to be more successful in developing support for implementation of public policies?

Presenters' Biographies

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Bruce Ames, Ph.D., is a professor of biochemistry and molecular biology and Director of National Institute of Environmental Health Sciences Center at the University of California, Berkeley. Dr. Ames has been the international leader in the field of mutagenesis and genetic toxicology for over 20 years; his work has had a major impact on basic and applied research on mutation, cancer, and aging. The development of Ames' mutagenicity test as a practical tool for the detection of potential carcinogens has led to its use in over 3,000 laboratories and in all the major drug and chemical companies. Dr. Ames is a member of the National Academy of Sciences and a former member of the board of directors of the National Cancer Institute (National Cancer Advisory Board). He was the recipient of the most prestigious award for cancer research, the General Motors Cancer Research Foundation Prize (1983), the highest award in environmental achievement, the Tyler Prize (1985), and the Gold Medal Award of the American Institute of Chemists (1991).

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John Córdova has worked in government or government-related projects for 30 years. His experience includes 10 years of work in Washington, D.C., 15 years in state and local government in New Mexico, and 5 years providing technical and evaluation assistance to Indian tribes and government agencies in the Rocky Mountain region. Most recently he has worked as a consultant to the Hirst Company, an Albuquerque-based public relations firm. The company provides public relations counseling to a number of clients, including Westinghouse Electric Company, which operates the Waste Isolation Pilot Plant (WIPP) in Carlsbad, New Mexico and Browning Ferris Industries of Houston, Texas. Mr. Córdova devoted much of his time to these clients, offering community relations advice, assistance, and counseling. He provided information on these projects to a number of state, local, and regional agencies and Indian tribes. Mr. Córdova has also served as a community relations counselor to Sandia National Laboratories and to the U.S. Department of Energy.

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Robert Cranwell received his Ph.D. in Mathematics (Stochastic Processes and Reliability Theory) in 1975 from Arizona State University. He then became an assistant professor of mathematics at Arizona State University and the University of Wisconsin. Since joining Sandia National Laboratories in 1978, Dr. Cranwell has directed the development and application of risk and reliability tools to assist U.S. industry and government agencies in manufacturing- and regulatory-related issues. For the past three years, he has directed a program with the Semiconductor Manufacturing Technology Consortium to enhance the reliability of semiconductor manufacturing equipment. He also directed the first Cooperative Research and Development Agreement signed at Sandia with Motorola, Inc. to evaluate the reliability of printed wiring boards manufactured under a new no-clean soldering process. Dr. Cranwell has served as an international consultant with the Nuclear Energy Agency, the Swedish Nuclear Power Inspectorate, and the Netherlands Central Organization for Radioactive Waste.

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Paul Slovic is President of Decision Research in Eugene, Oregon, and a professor of psychology at the University of Oregon. During the past 15 years, Dr. Slovic and his associates have developed methods for describing risk perceptions and measuring their impacts on individuals, industry, and society. They have created a taxonomic system that enables one to understand and predict perceived risk, attitudes toward regulation, and the impacts resulting from accidents or failures. Dr. Slovic has been a consultant to numerous companies and government agencies. He is a member of the National Council on Radiation Protection and Measurements and a past president of the Society for Risk Analysis.

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Videotape/Videoconference Training Series

The need for information and technologies about hazardous waste and waste management is critical, as public concern increases. By eliminating the cost of travel and per-diem budgets, these videotape training series address the issue in a cost-effective manner. The low cost of videotape programming means that more people can be trained for the same investment.

These series have been developed and are presented by the New Mexico Waste-management Education and Research Consortium (WERC), a collaboration of New Mexico State University, University of New Mexico, New Mexico Institute of Mining and Technology, Sandia National Laboratories, Los Alamos National Laboratory, and Navajo Community College (affiliate member). WERC is funded by the U.S. Department of Energy. The consortium works together to address hazardous waste issues, facilitating technology transfer, education, training and research in hazardous waste.

CERTIFICATION: WERC awards an official certificate to all students completing the series. CEUs are available. WERC also offers credit courses on KU-band satellite from the three participating universities. Call for details.

Waste Minimization and Pollution Prevention

Although it is impossible to have entirely "clean" manufacturing, we can drastically cut the generation of all waste from nearly all processes. Further, much of what we call "waste" is often an unused by-product that could be further processed or refined and sold as a product. Often toxic waste generated as a by-product of manufacturing can be reduced dramatically through better process control, or avoided entirely by an alternate process.

1. Overview — Why Minimize Waste?
Co-Leaders: Joan Woodard, Ph.D., Sandia National Laboratories, Mary Ann Baker, Esq., NM Environment Dept.
- What is waste minimization?
- Beyond compliance—waste minimization makes good business sense from a cost/benefit perspective
- Federal regulations (existing and proposed) and State samples
- Determining baselines—how is it done?
- Goal setting/Looking for opportunities
- How waste minimization affects small businesses
- International concerns/Issues

2. Where Do We Start Waste Minimization?
Lead Presenter: Jeff Weinrach, Ph.D., Los Alamos National Laboratory
- The need for assessments
- The methods for assessments
- The goals for assessments
- The follow-through to assessments

3. How Does Recycling/Reuse/Reclamation Make Economic Sense?
Lead Presenter: John Hernandez, Ph.D., NM State University
- Marketable products as by-products
- How to avoid permitting
- Myths versus facts
- The world view: In-process materials substitutions
- Packaging
- Not changing the front-end processes, changing middle
- Case studies (Siemens, etching)

4. Are the Right Product/Process Designs Being Addressed?
Lead Presenter: Robert V. Fultyn, Sc.D., Digital Equipment (retired)
- How to get it right from the start
- How to use TQM approaches to lower environmental impact
- Concurrent engineering
- New concepts for product and process design
- Discovering and evaluating alternative materials and methods
- Cost effectiveness of redesign
- Measuring and controlling
- Continuous improvement

5. Solvents and Organic Chemicals
Co-Leaders: Barry Granoff, Ph.D., Sandia National Laboratories, Jon Nimitz, Ph.D., University of New Mexico
- Overview and purpose
- Alternative chemicals
- Alternative processes
- Systems and cost/benefit analyses
- Success stories
- Beyond compliance

6. How to Implement Minimization in Metals, Plating, and Electrical Interconnects
Lead Presenter: Fred Kear, Ph.D., Siemens Stromberg-Carlson
- Waste minimization opportunities in metallization and soldering
- The regulatory impetus for minimizing waste
- Electroplating waste reduction: process changes and recycling
- Lead legislation and electronic soldering alternatives
- Health-related risks associated with lead use
- Alternate processes/Materials for electronic interconnects

7. How to Minimize "End of Life" Problems
Lead Presenter: Larry L. Barton, Ph.D., University of New Mexico
- Before the cradle and beyond the grave
- Liability and federal regulations
- Case studies and success stories
- Lead/acid batteries and other products
- Waste incompatibilities and corrosion

8. Wrap-Up
Lead Presenter: Robert H. Neill, Environmental Evaluation Group
- Focus on case studies, direct applications
- Tying it all together
- Where do we go from here?
- A detailed example
- Lessons learned
- What worked/What didn't
- Risk assessment
- Impact on global environment

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Videotape Training Series

Waste Minimization Lead Presenters

Mary Ann R. Baker, Esquire, is an Assistant General Counsel for the New Mexico Environment Department (NMED), concentrating on RCRA/UST regulatory enforcement and litigation, CERCLA negotiations, and advising NMED's management on a wide variety of environmental law issues. In addition, she teaches a course on Hazardous Materials Regulations Applicable in New Mexico at the Santa Fe Community College.

Larry Barton, Ph.D., is a faculty member of the UNM Biology Department, where his laboratory studies the microbial transformation of lead, selenium, and chromium. He has also worked with the Dept. of Biochemistry at the University of Georgia and the School of Health and Hygiene at Johns Hopkins University. His research includes physiological activities of microorganisms, focusing on metabolism of inorganic compounds by bacteria.

Robert V. Fultyn, Sc.D., served as a staff member at Los Alamos National Laboratory for over 17 years, engaged in data analysis and modeling of atmospheric phenomena; computer-based laboratory instrumentation; and administrative data processing techniques. He recently retired from Digital Equipment Corporation, after more than ten years of involvement in the advancement of quality and productivity issues by statistical data analysis.

Barry Granoff, Ph.D., is Manager of the Environmentally Conscious Manufacturing (ECM) Programs at Sandia National Laboratories, where his work focuses on waste minimization and pollution prevention, with an emphasis on precision cleaning and solvent substitutes for chlorofluorocarbons and chlorinated hydrocarbons. Prior to this, he had worked in materials science, process chemistry, and energy conversion. He has been involved in numerous technical programs.

John Hernandez, Ph.D., has been a professor of Civil Engineering at NM State University for the past 25 years, specializing in water quality management. He has served at both the state (New Mexico Department of Public Health) and at the federal level (Deputy Administrator of the U.S. Environmental Protection Agency). He has broad experience in the management of solid and hazardous wastes and in the regulatory structure on which design criteria is based.

Fred Kear is a Staff Process Engineer at Siemens Stromberg-Carlson, involved with manufacturing issues and environmental and OSHA compliance. His memberships include: Siemens USA Environmental Network; U.S. Chamber of Commerce; Occupational Health and Safety Council; and the Electronics Industry Ad Hoc Lead Committee. He has authored five engineering texts dealing with process engineering and printed circuit manufacture.

Jon Nimitz, Ph.D., joined the NM Engineering Research Institute as a Senior Scientist after teaching chemistry at the University of New Mexico for several years. His specialties include development, assessment, and review of alternative chemicals and processes to minimize ozone depletion, global warming, and nuclear wastes. He has co-authored over 30 technical reports and papers, plus an organic chemistry laboratory textbook.

Jeff Weinrach, Ph.D. earned his doctorate in physical-inorganic chemistry from the University of Wisconsin-Milwaukee in 1987. He has served as a staff member on the Waste Minimization Team for two years. He is technical coordinator for the Los Alamos National Laboratory Waste Minimization Program. During the past two years he has delivered 13 presentations regarding waste minimization and pollution prevention.

Joan Woodard, Ph.D., is Director of Manufacturing and Environmental Research and Development Programs at Sandia National Laboratories. She is responsible for research and development in waste minimization, waste treatment, instrumentation, remediation, and waste management. Her earlier work at Sandia included material characterization, combustion research, and solar thermal systems research.

Hazardous Waste Management

This training program recognizes the critical nature of waste management in light of the serious ecological problems confronting the country. The series incorporates the latest technology and research, showing practical application for business, industry, research and educational facilities across the country.

1. ***What Is Waste?***
   Leader: Toni K. Ristau, Geoscience Consultants, Ltd.

2. ***Risks Associated with Hazardous and Radioactive Wastes***
   Leader: John Hernandez, Ph.D., NM State University

3. ***Transport Processes Related to Wastes***
   Leader: John W. Wilson, Ph.D., NM Institute of Mining & Technology

4. ***Waste Form Modification***
   Leader: David Kauffman, Ph.D., University of New Mexico

5. ***Site Characterization***
   Leader: Randall T. Hicks, Geoscience Consultants, Ltd.

6. ***Sampling and Analysis***
   Leader: Craig Scott Leasure, Los Alamos National Laboratory

7. ***Soil and Groundwater Remediation I: Physical/Chemical Processes***
   Leader: Adrian Hanson, Ph.D., NM State University

8. ***Soil and Groundwater Remediation II: Biological Processes***
   Leader: Ricardo Jacquez, Ph.D., NM State University

9. ***Radiation and Radioactive Materials***
   Leader: Glenn D. Pierce, Ph.D., Oak Ridge National Laboratory

10. ***Radioactive and Mixed Wastes Management***
    Leader: Bruce M. Thomson, Ph.D., University of New Mexico

11. ***Waste Minimization and Series Close***
    Leader: Joan B. Woodard, Sandia National Laboratories

Toni K. Ristau served as the Southwest Regional Director for Geoscience Consultants, Ltd. and provided technical support as an environmental engineer, architect and environmental attorney. She has over 18 years of professional experience in environmental regulatory compliance and enforcement and environmental project/program management. Ms. Ristau has worked as program manager for the CERCLA section for the State of Utah and as Director of Western States Hazardous Waste Project through the Attorney General's Office in Arizona.

John Hernandez, Ph.D., has been a professor of Civil Engineering at NM State University for the past 25 years, specializing in water quality management. He has served at both the state (New Mexico Department of Public Health) and at the federal level (Deputy Administrator of the U.S. Environmental Protection Agency). He has broad experience in the management of solid and hazardous wastes and in the regulatory structure on which design criteria are based.

John Wilson, Ph.D.,is a professor and Director of the Hydrology Program at New Mexico Institute of Mining and Technology in Socorro. He is currently a delegate to the Universities Council on Water Resources, and associate editor of the journal, "Hazardous Waste." Dr. Wilson chairs the Groundwater Hydrology Committee of the American Geophysical Union and is a member of the Committee on Flow in Porous Media, International Association for Hydraulic Research. Dr. Wilson also serves as Vice-Chairman of the Science Advisory Committee, EPA Western Region Hazardous Waste Research Center, Stanford University.

David Kauffman, Ph.D., is the Associate Dean of the College of Engineering at the University of New Mexico. He is also an associate professor of Chemical and Nuclear Engineering. His areas of specialization include chemical engineering; process plant design; safety and reliability; environmental engineering; geothermal energy; kinetics and catalysis; and engineering design education. Dr. Kauffman is the Technical Leader of Education Programs for WERC.

Randall T. Hicks is a Certified Professional Geologist specializing in hydrogeology, groundwater monitoring programs, contaminant transport in the unsaturated zone, and geochemistry. Mr. Hicks has directed projects involving the design and installation of waste management systems for many large industrial clients, ranging from fiberboard manufacturers to oil refineries. In addition, he has performed geohydrologic evaluations of hazardous waste sites, RCRA and CERCLA sites, municipal wastewater treatment plants, and other facilities. He is the co-author of the 1981 Underground Injection Control Regulations for the state of New Mexico. Mr. Hicks serves as the Senior Vice-President of Technical Services for Geoscience Consultants, Ltd.

Craig Scott Leasure is Health and Environmental Chemistry Group Leader at Los Alamos National Laboratory. He is responsible for chemical analyses supporting radiation protection, industrial hygiene, waste management and environmental compliance activities. Earlier work at Lockheed included applied research and test projections in support of space shuttles and space stations and environmental analysis air, water. and soil.

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Hazardous Waste Management Lead Presenters

Adrian T. Hanson, Ph.D., is an assistant professor in Environmental Engineering with the Civil Agricultural and Geological Engineering Department at New Mexico State University. Working as a project engineer for a consulting firm, Dr. Hanson has had practical experience in municipal, industrial, and hazardous waste treatment. He teaches all phases of environmental engineering, but specializes in chemical/physical treatment. His research has involved diverse topics from in-situ sludge digestion for the reclamation of eutrophic lakes to the effect of temperature on turbulent flow field structure and metal chemistry in flocculation. He is currently researching the reclamation of metals contaminated soils using heap leaching.

Ricardo Jacquez, Ph.D., is a professor of Civil Engineering at New Mexico State University. Dr Jacquez is a Technical Head of the Research and Education Programs for WREC. He is a registered professional engineer in the state of New Mexico. His areas of specialization include environmental engineering; bioremediation of domestic, industrial and hazardous wastes; groundwater monitoring and remediation; and hazardous waste management.

Glenn D. Pierce, Ph.D., earned a doctorate in Civil Engineering (Environmental Engineering Option) from the University of New Mexico. Dr. Pierce has 13 years of experience in radioactive waste management. He is a former Waste Management Engineer for Argonne National Laboratory-West. Since 1985, he has provided engineering support to the U.S. DOE TRU Waste program. He is currently supporting design review activities for the Waste Handling and Packaging Plant, a processing facility for remote handled TRU waste, at Oak Ridge National Laboratory.

Bruce Thomson, Ph.D., is an associate professor with the Department of Civil Engineering at the University of New Mexico. Dr. Thomson served as a visiting professor of the Environics Division, US Air Force Engineering Services Center at Tyndall AFB in Florida. He has also consulted for the United Nations Industrial Development Organization in Chile; Sandia National Laboratories; Deuel and Associates; Sullivan Design Group; and Intel Corporation, all in New Mexico. He is the author of Deserts as Dumps: The Disposal of Hazardous Materials in Arid Ecosystems.

Joan Woodard, Ph.D., is Director of Manufacturing and Environmental Research and Development Programs at Sandia National Laboratories. She is responsible for research and development in waste minimization, waste treatment, instrumentation, remediation, and waste management. Her earlier work at Sandia included material characterization, combustion research, and solar thermal systems research.

Total Quality Management

TQM has been defined as "A cooperative form of doing business that relies on the talents and capabilities of both labor and management to continually improve quality and productivity using teams" (Jablonski, 1990).

This training is based on the American experts' philosophy of quality. It incorporates expertise from industry and academia with a unique engineering/management approach. The series assists organizations moving toward Total Quality Management and sharpens the skills of those already implementing Total Quality Management. The series addresses all aspects of TQM—including technical, organizational, behavioral, and managerial considerations.

Choose one of three introductory programs orienting the series to:

Government
- Federal recognition programs for applying these concepts
- The Federal Quality Institute
- Relevant applications of continuous process improvement
- Networking as a money-saving and benchmarking aid
- A historical perspective of quality in government
- The need for Total Quality Management
- Management issues which arise from an organization's movement toward TQM

Manufacturing
- A historical perspective on quality
- The need for Total Quality in U.S. manufacturing
- How teams are used to bring improved products to market faster
- Team techniques case studies
- The important role of employee and supplier involvement
- How an organization implements quality
- The application of TQM to downsizing organizations
- The Malcolm Baldrige National Quality Award as a standard of excellence

Improving Your Competitive Position
- Developing Quality requirements for Requests for Proposals (RFPs)
- Responding to quality requirements in RFPs
- Examples of how quality is surfacing in RFPs and contracts
- Creating partnerships with your suppliers
- TQM as a "Strategic Competitive Tool"
- Applications in both manufacturing and services
- White-collar application of quality to professional services
- The Malcolm Baldrige National Quality Award as a standard of excellence

Program Titles
1. ***Introduction and Implementing TQM in Your Organization***
2. ***Organizational Change and Leadership in TQM***
3. ***Selecting and Understanding Processes for Improvement in TQM***
4. ***Team Involvement and Measurement***
5. ***Data Analysis and Design of Experiments***
6. ***Implementing Process Change and Institutionalizing TQM in Your Organization***

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Total Quality Management Lead Presenters

Joseph E. Champoux, Ph.D., is the James L. Rutledge Professor of Management at the Robert O. Anderson Schools of Management of the University of New Mexico. He received his Ph.D. in Administration from the University of California, Irvine, and joined the Anderson Schools' faculty in 1972. He teaches graduate and undergraduate courses in Organizational Theory and Organizational Behavior.

Larry Cox had 26 years of management experience. serving most recently as a senior Department of Defense manager in the government contracts arena. He successfully implemented TQM in a 700-person organization. Variability was reduced in 23 critical processes, resulting in reduced rework, shorter production flow times and fewer customer defect reports. He holds a B.S. degree in Business Administration and an M.A. in Psychology. He is a certified professional contracts manager.

Paul Hartman has 15 years of involvement with learning, promoting, teaching, and facilitating Total Quality Management concepts and techniques. He is Manager of Quality Services with UNC Analytical Services. He provides training and support services to the Department of Energy, as well as business and industry in the private sector.

Joseph R. Jablonski received his B.S. in Mechanical Engineering from the University of New Mexico. He is President of Technical Management Consortium, Inc., a professional services firm specializing in Quality and Technical Project Management. Author of *Implementing TQM: Competing in the 1990s*, he routinely consults with private and government organizations on the implementation of TQM and development of quality-related issues.

Joe H. Mullins, Ph.D., is the Director of Manufacturing Engineering at the University of New Mexico. He received both his M.S. and Ph.D. in Physics from the California Institute of Technology. Dr. Mullins had served on the faculty of the California Institute of Technology and has been the director of several laboratories while with AT&T Bell Laboratories.

Richard H. Williams Ph.D., is a Professor of Electrical and Computer Engineering and a Research Professor of Neurology at the University of New Mexico. Professor Williams teaches graduate and undergraduate courses in digital electronics, circuits and systems, fields and waves, and digital signal processing. He is currently writing a textbook on probabilistic methods for electrical engineers.

Steven Yourstone, Ph.D., is a Professor of Production and Operations Management at the Robert O. Anderson Schools of Management at the University of New Mexico. He received his Ph.D. from the University of Washington. His research and publications are in statistical quality control. Professor Yourstone recently published research focusing on real-time quality control in the journal, "Quality and Reliability Engineering International."

Radioactive Waste Management

The training series will begin with a general review of radioactivity and health physics and lead into discussions of the major national programs associated with radioactive waste management and disposal: uranium mill tailings, low-level waste, high-level waste, and transuranic wastes. The final program will address new technologies and international radioactive waste management programs currently under development.

This series is broadcast on C-band and NTU. Facilities with a satellite dish anywhere in the United States can receive this series, providing on-site training for all interested employees.

1. Introduction to Radioactive Waste Management–March 3, 1993
Co-Leaders: Bruce Thomson, Ph.D., University of New Mexico
James Johnson, Ph.D., University of New Mexico
- Types of radioactivity
- Sources of radioactive waste
- Federal regulations (NRC & EPA)
- Waste characterization
- Examples of waste
- Waste classification

2. Interactions Between Radiation and Matter–March 31, 1993
Co-Leaders: Robert Murphy, Ph.D., Benchmark Environmental Corp.
James Johnson, Ph.D., University of New Mexico
- Decay kinetics
- Interactions of radiation with matter
- Radiation measurement
- Biological effects
- Health physics
- Inhalation Toxicology

3. Decommission and Decontamination–April 28, 1993
Co-Leaders: Glenn Pierce, Ph.D., The S.M. Stoller Corporation
Charles Reith, Ph.D., Jacobs Engineering Group
- Technologies for dealing with surfaces, soils, and water
- Waste minimization
- Volume reduction
- Federal land disposal restrictions
- Mixed-waste management

4. Transportation Issues in Radioactive Waste Management and UMTRA–May 26, 1993
Leader: James Brogan, Ph.D., University of New Mexico
Co-Leaders: Charles Reith, Ph.D., Jacobs Engineering Group
Jack Caldwell, Jacobs Engineering Group
Part 1. Transportation issues
- Containers, routes, risk, and emergency response

Part 2. UMTRA Program & Near Surface Disposal Design
- Uranium mill tailings characteristics
- Regulations (Title I vs. Title II sites)
- Disposal cell technology and applications to near surface disposal of LLW and hazardous waste

5. Low-Level Radioactive Waste (LLW) Management–June 9, 1993
Leader: Bruce Thomson, Ph.D., University of New Mexico
- LLW characteristics, sources, and regulations
- Status of compacts
- Current federal and commercial practice for LLW disposal
- Incineration
- Naturally-occurring radioactive materials (NORMs)

6. High-Level Radioactive Waste (HLW) Management–September 8, 1993
Co-Leaders: Jonathan Myers, Ph.D., IT Corporation
Bob Busch, Ph.D., University of New Mexico
- HLW characteristics, sources, and regulations
- Waste forms
- Natural analogs
- Yucca Mountain

7. Transuranic Radioactive Waste (TRU) Management–October 13, 1993
Leader: Kevin Donovan, Westinghouse
- TRU characteristics, sources, and regulations
- Waste forms
- WIPP

8. New and Other Technologies for Radioactive Waste Management–November 3, 1993
Co-Leaders: D.R. "Rip" Anderson, Ph. D., Sandia National Laboratories
Rodney Ewing, Ph.D., University of New Mexico
- Radionuclide migration: use of natural analogs
- New waste forms
- Subseabed disposal
- Transmutation
- International Programs
- Wrap-up series

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Radioactive Waste Management Lead Presenters

Technical Advisor
Bruce Thomson, Ph.D., is an associate professor in the Department of Civil Engineering at the University of New Mexico. He received his B.S. in civil engineering at the University of California, Davis, and his M.S. and Ph.D. degrees in environmental science and engineering from Rice University in Houston, TX.

James Brogan, Ph.D., earned his doctorate in civil engineering from the University of Tennessee. His areas of expertise include transportation planning, transportation engineering, traffic engineering and highway safety.

Robert D. Busch, Ph.D., is Director of the Environmental Radiation Measurements Laboratory at the University of New Mexico, where he is responsible for acquiring equipment and performing quantitative analyses of radiation levels in soil, air, and water. Dr. Busch earned his M.S. and Ph.D. in nuclear engineering from the University of New Mexico.

Jack A. Caldwell is a civil and geotechnical engineer with 22 years experience in waste management. As Operations Manager for the Jacobs Engineering Group, Inc., he is responsible for the management of engineering and environmental restoration projects. Previously, as Manager of Engineering on the DOE UMTRA Project, his primary responsibility was the engineering of the 24 disposal cells for the DOE's Uranium Mill Tailings Remedial Action Project.

Kevin S. Donovan is the Manager, TRU System Integration, Westinghouse Waste Isolation Division, at the Waste Isolation Pilot Plant in New Mexico. He provides technical support to the U.S. DOE WIPP Project Integration Office in areas pertaining to integration of waste management activities related to geologic disposal of transuranic waste. Included in these activities are TRU waste characterization, waste certification, and transportation.

Rodney Charles Ewing, Ph.D., earned a Ph.D. with distinction from Stanford University in 1974. He has been involved in nuclear waste disposal research since 1978 and has worked with scientists at various national laboratories. He also collaborates with the Hahn-Meitner Institute and the European Institute for Transuranium Elements in Germany; the Commissariat L'Energie Atomique in France; Atomic Energy Canada; and the Swedish Nuclear Fuel and Waste Management Company.

James E. Johnson, Ph.D., is a research professor in the Department of Chemical and Nuclear Engineering at the University of New Mexico. He earned an undergraduate degree in chemistry and an M.S. and Ph.D. (1965) in health physics (radiation protection) from Colorado State University.

Jonathan Myers, Ph.D., holds a doctorate in geochemistry and has eleven years of professional experience in the management, storage, treatment, and disposal of hazardous and radioactive waste. His specialty involves applying computer simulation techniques for designing waste isolation systems; predicting interactions between contaminants, soil, rock, and groundwater; and predicting the fate of hazardous, low-level, transuranic, and high-level radioactive substances released into the environment. He is currently manager of the Hydrologic and Geotechnical Assessments Group for I.T. Corporation in Albuquerque, N.M.

Robert O. Murphy, Ph.D., earned a doctorate in nuclear engineering (health physics option) from Georgia Institute of Technology. Dr. Murphy has 13 years experience in nuclear industry, including the last five in radioactive waste management.

Glenn D. Pierce, Ph.D., has a doctorate in civil engineering (environmental engineering option) from the University of New Mexico. Dr. Pierce has 13 years of experience in radioactive waste management. He is a former Waste Management Engineer for Argonne National Laboratory-West.

Charles Reith, Ph.D., earned his Ph.D. in ecology from the University of New Mexico. He is the Manager of Technology Development for Jacobs Engineering Group at a Central-California Air Force Base. Formerly he worked at the Weldon Springs Site Remedial Action Project (WSSRAP), a DOE project to clean up contaminated structures and mixed wastes at a former uranium production facility near St. Louis, Missouri.

D. Richard Anderson, Ph.D., has worked at Sandia National Laboratories for the past 31 years and is currently Supervisor of the WIPP Performance Assessment and Ocean Programs Division. He earned his doctorate in Theoretical Organic Chemistry and Chemical Oceanography from Oregon State University.

Environmental Risk Management

Increasingly aware of environmental issues, the American public has begun to demand accountability concerning the management of environmental risks. Government, business, and industry must respond by characterizing and assessing these risks and then effectively communicating with a variety of public groups about the risk-based decisions they make. This series covers primary technical concepts, social concerns, and communication issues as they apply to environmental risk management.

This series is broadcast on C-band and NTU. Facilities with a satellite dish anywhere in the United States can receive this series, providing on-site training for all interested employees.

1. Risk: Terminology, Concepts, Methods, Applications; Why Risk Communication Is Difficult–February 10, 1993

Program Leader: Albert O. Bendure, PhD., Sandia National Laboratories

- Interaction between technical and social risk perspectives
- Hazard, risk, and safety
- Definitions and measures of risk
- Public risk (examples and comparisons)
- Risk study methodology
- Complex dynamics of risk communication
- The role of trust

2. How Do We Decide What Is Risky? Technical and Social Methods for Identifying Risk – March 10, 1993

Program Leaders: William Hadley, Ph..D, University of New Mexico
Lynn Anspaugh, Ph.D., Lawrence Livermore National Laboratory

- Identification of hazards
- Assessing risks to human health
- Assessing risks to ecological receptors
- Epidemiological and toxicological studies
- Bases of public perceptions of risks to human health and the environment
- Uncertainties in risk determinations

3. Identifying the Gap: Divergent Technical and Social Models for Risk Characterization–April 14, 1993

Program Leader: Bruce Kelman, Ph.D., New Mexico State University
Failure Analysis Associates

- Technical models for risk characterization
- Social models for risk characterization
- Natural vs. technological hazards
- Voluntary vs. involuntary risks
- The mass media and the "social amplification of risk"
- Distribution of risks

4. Quantification of Models for Risk Assessment–May 12, 1993

Program Leader: Stanley M. Nealey, Ph.D, Battelle Seattle Research Center

- Risk-based environmental regulations
- Where do the numbers come from?
- Types and sources of data
- Measuring uncertainty and public perceptions of risk
- Role of the mass media
- Public perceptions of science and scientific uncertainty
- Public responses to scientific disputes over risk
- Public trust and perceptions of risk

5. Risk Characterization: Synthesis and Communication–September 1, 1993

Program Leader: Charles D. Hundertmark, Jacobs Engineering Group, Inc.

- Bridging the gap between technical and social characterizations of risk
- Traditional approaches (one-way flow, experts to public)
- Alternative approaches (two-way flow)
- Trust and public reaction to technological risks

6. Risk Assessment: Communicating Results and Public Perception–September 29, 1993

Program Leader: Robert Luna, Ph.D., Sandia National Laboratories

- Risk-based decision making
- Communicating results: Formal and informal processes
- Trust revisited–difficulties of maintaining or restoring trust
- Incorporating public input into the process
- Issues of risk acceptability
- Issues of compensation

7. Risk-Based Decision Making: A Final Act?–October 27, 1993

Program Leader: Desmond Stack, Los Alamos National Laboratory

- Optimal allocation of risk-reduction resources
- Realization of diminishing returns (when to stop)
- Design and engineering with the public in mind
- Practical applications of public concerns
- Rethinking permanence of design
- Other strategies
- Learning how to learn as we go
- Tools for retaining knowledge and experience
- Making the most of public input
- Wrap-up of Risk Series
- Introduction to next series

Hank C. Jenkins-Smith, Ph.D., serves as a Technical Advisor for the series. Professor Jenkins-Smith is a specialist in the areas of risk perception, public policy analysis, natural resource policy, and methodology. He is on the faculty of the University of New Mexico Department of Political Science, and is former Director of the UNM Institute for Public Policy and UNM's Survey Research Center.

A. Sharif Heger, Ph.D., P.E., serves as a Technical Advisor for the series. Professor Heger is an assistant professor at the University of New Mexico and a visiting professor at Sandia National Laboratories. He teaches nuclear reactor theory at UNM and has done active research in waste management and probabilistic risk assessment. He is currently working in conjunction with Sandia National Laboratories and AT&T developing a decision support system for performance assessment of waste repositories.

Lynn R. Anspaugh, Ph.D., is a biophysicist and the Division Leader of the Environmental Sciences Division at the Lawrence Livermore National Laboratory (LLNL), and Co-Director of the LLNL–University of California, Davis, Risk Sciences Center/Program. Dr. Anspaugh is the Scientific Director of the Basic Environmental Compliance and Monitoring Program at the U.S. Nevada Test Site, and the U.S. leader of the Joint Coordinating Committee on Civilian Nuclear Reactor Safety's Working Group 7.1 on Environmental Transport.

Albert O. Bendure, M.S.E.E., is a Senior Member of Technical Staff in the Risk Management and NEPA Department of Sandia National Laboratories. He is the leader of Sandia's Risk Management Team, responsible for the risk management process for Sandia's facilities and operations. Mr. Bendure has over 24 years of experience in microelectronics and semiconductor manufacturing, including eight years in managing the environment, safety, health, and waste-management functions for an integrated circuit production facility.

William M. Hadley is Dean of the University of New Mexico College of Pharmacy, a professor of pharmacy, and an adjunct scientist at the Lovelace Inhalation Toxicology Research Institute. Dr. Hadley has developed and taught a variety of courses, including general toxicology, biochemical pharmacology/toxicology, analytical toxicology, and pollution toxicology. He is the author or co-author of more than 50 scientific presentations and publications.

Charles A. Hundertmark, M.A., APR, is the Communication Training Specialist for Jacobs Engineering Group, Inc., where he has developed and conducted risk communication training for the DOE's Uranium Mill Tailings Remedial Action (UMTRA) Project; Accident Response Groups at Los Alamos National Laboratory and Sandia National Laboratories; the New Production Reactor Program; and the National Defense Executive Reserve.

Bruce J. Kelman, Ph.D., D.A.B.T., is Manager of Toxicology at Failure Analysis Associates, Inc. and an adjunct professor at New Mexico State University. Dr. Kelman's research has focused on components of health risk models, including mechanistic studies aimed at quantitating exposure of critical organ systems. Associated with these activities, Dr. Kelman has presented a variety of health risk concepts to policy makers, government regulators, citizen groups, and individuals involved in all aspects of the legal process.

Robert E. Luna, Ph.D., P.E., is Acting Manager for the Transportation System Development Department at Sandia National Laboratories, where he maintains the original radioactive material transportation R&D program for DOE-EM50. He also works to broaden the scope of this program to include hazardous materials and mixed waste predisposal problems and develops transportation-related programs with DOT, NRC, and DoD.

Stanley M. Nealey, Ph.D., is a Research Sceintist at the Environmental Planning and Social Research Center, part of the Battelle Human Affairs Research Centers in Seattle, WA. In a diverse carreer spanning twenty years, Dr. Nealey has taught, conducted research and managed a wide variety of research projects. Public concern about advanced technology, and particularly societal controversy over nuclear power and waste, is one focus of Dr. Nealey's research.

Desmond Stack M.A., M.S., has 15 years experience performing probablistic risk assessments (PRAs) for the Nuclear Regulatory Commission and the Department of Energy at Sandia National Laboratories and Los Alamos National Laboratory. At Sandia, Mr. Stack helped develop the SETS computer code and its applications for PRA, vital area analysis, and common cause analysis. At Los Alamos, he was principal investigator for a number of PRAs. He is currently the section leader for the Probabilistic Safety Assessment section in the Engineering and Safety Analysis group.

WERC/ITV Spring Courses

Electrical and Computer Engineering

EECE 213 CIRCUIT ANALYSIS II
EECE 340 PROBALISTIC METHODS
EECE 362 FIELDS AND WAVES
EECE 440 COMPUTER NETWORKS
EECE 441 INTRO TO COMMUNICATION SYSTEMS
EECE 445 INTRODUCTION TO CONTROL SYSTEMS
EECE 461 ANTENNAS AND PROP
EECE 472 MICRO ELECTRONICS
EECE 495/595/ME 462/562 DESIGN FOR MANUFACTURING
EECE 512 MODERN NETWORK THEORY
EECE 516/CS 532 COMPUTER VISION
EECE 517/CS 531/MATH 566 PATTERN RECOGNITION
EECE 520 VLSI DESIGN
EECE 538 ADVANCED COMPUTER DESIGN
EECE 539 DIGITAL SIGNAL PROCESSING
EECE 546 MULTI VARIABLE CONTROLS
EECE 548 FUZZY LOGIC
EECE 567 ADVANCED OPTICS II
EECE 572 SEMI CONDUCTOR AND PROP
EECE 576 FIELD EFFECT DEVICES
EECE 595 QUANTUM WELL MATERIALS
EECE 595 INTELLIGENT CONTROL
EECE 630 FAULT TOLERANT COMP
EECE 649 T/ROBUST CONTROL
EECE 595/CS 491/591 PARALLEL ALGORITHMS

Computer Science

CS 350 PROGRAMMING PRACTICUM
CS 363 FUNDAMENTALS OF DATA STRUCTURES
CS 457/490 PRIN OF ARTIFICIAL INTELLIGENCE MACHINES
CS 463 STORAGE AND RETRIEVAL OF INFO
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