Assessing Environmental and Occupational Risks and Protecting Public Health

Dr. Raymond D. Harbison
College of Public Health
University of South Florida

rharbiso@ix.netcom.com
Risk

- Risk can be defined as the likelihood of an unwanted occurrence coupled with an element of uncertainty about when the risk might occur.
<table>
<thead>
<tr>
<th>Name</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rachel Carson</td>
<td>1962</td>
</tr>
<tr>
<td>Clean Water Act</td>
<td>1972</td>
</tr>
<tr>
<td>Clean Air Act</td>
<td>1970</td>
</tr>
<tr>
<td>Resource Conservation and Recovery Act</td>
<td>1976</td>
</tr>
<tr>
<td>Toxic Substances Control Act</td>
<td>1976</td>
</tr>
</tbody>
</table>
Comprehensive Environmental
Response, Compensation and
Liability Act CERCLA (Superfund)

Worker Right-to-Know

Superfund Amendments and
Reauthorization Act (SARA)

1980

1986
What Are Chemicals?

• Everything in your life except light, radiation and sound waves.
• Chemicals are plants, food, cars, and other living things
# Doses of Common Substances

<table>
<thead>
<tr>
<th>Substance</th>
<th>Normal/Unharmful Dose</th>
<th>Lethal Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water</td>
<td>1.5 Quarts</td>
<td>15 Quarts</td>
</tr>
<tr>
<td>Aspirin</td>
<td>2 Tablets</td>
<td>90 Tablets</td>
</tr>
<tr>
<td>Beer</td>
<td>1 Beer (15 mg/dl or 0.015%)</td>
<td>33 Beers (500 mg/dl or 0.5%)</td>
</tr>
<tr>
<td>Salt</td>
<td>3 Level Teaspoons</td>
<td>60 Level Teaspoons</td>
</tr>
<tr>
<td>Lima Beans (Cyanide)</td>
<td>0.036-1.18 mg/day (eating lima beans)</td>
<td>106 mg</td>
</tr>
</tbody>
</table>
Chemical-Induced Effects

- Acute-mucous membrane irritation, drowsiness-immediate/transient
- Delayed-hepatotoxicity-48/72 hours
- Chronic toxicity-cirrhosis of the liver
- Carcinogenicity-hepatocarcinoma
Chemicals

Introduction
– In the United States, there are currently more than 70,000 synthetic chemicals currently in commercial use, and for most of them, their toxicity is not well known or understood.
Chemicals

Introduction
– Since 1,000 - 2,000 new chemicals are introduced each year into our society, there is significant opportunity for untested materials to enter our environment and expose humans, wildlife, and plants to toxic effects.
Hazard

Introduction

– A chemical is not a hazard unless contact is made in a form and quantity that can cause harm.
Hazardous Substance

– A hazardous substance is defined in the Comprehensive Environmental Response Compensation and Liability Act (CERCLA) as any chemical regulated under the following Acts:

• Clean Air Act (CAA)
• Toxic Substances Control Act (TSCA)
• Clean Water Act (CWA)
Toxic Substance

• Toxic substances are those that:
  – (1) can produce reversible or irreversible bodily injury;
  – (2) have the capacity to cause tumors, neoplastic effects, or cancer;
  – (3) can cause reproductive errors including mutations and teratogenic effects;
Toxic Substance

• Toxic substances are those that:
  – (4) produce irritation or sensitization of mucous membranes;
  – (5) cause a reduction in motivation, mental alertness, or capability;
  – (6) alter behavior; or cause death of the organism.
EXPOSURE AND ENTRY ROUTES

• Exposure
  – In order for a toxic substance to produce its harmful effects on the human body, a person must first be exposed to the chemical.
Example of a Dose-Response Curve
An Example of Dose and Response

<table>
<thead>
<tr>
<th>Dose</th>
<th>Response</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of 325 mg ASPIRIN tablets</td>
<td>• Reduce risk of heart attacks</td>
</tr>
<tr>
<td></td>
<td>• Relief of headaches and minor aches and pains</td>
</tr>
<tr>
<td></td>
<td>• Relief of arthritis and rheumatoid condition</td>
</tr>
<tr>
<td></td>
<td>• Treatment of acute rheumatic fever</td>
</tr>
<tr>
<td></td>
<td>• Adult lethal dose</td>
</tr>
</tbody>
</table>
# Actual Toxicity and Ranking

<table>
<thead>
<tr>
<th>Agents</th>
<th>$LD_{50}$</th>
<th>Expected Human Dose</th>
</tr>
</thead>
<tbody>
<tr>
<td>PCBs</td>
<td>14,000</td>
<td>1 Quart</td>
</tr>
<tr>
<td>Alcohol</td>
<td>10,000</td>
<td>1 Pint-1 Quart</td>
</tr>
<tr>
<td>Table salt</td>
<td>4,000</td>
<td>1 Pint</td>
</tr>
<tr>
<td>Iron</td>
<td>1,500</td>
<td>1 Ounce-1 Pint</td>
</tr>
<tr>
<td>DDT</td>
<td>100</td>
<td>1 Teaspoon-1 Ounce</td>
</tr>
<tr>
<td>Strychnine</td>
<td>2</td>
<td>4 Drops</td>
</tr>
<tr>
<td>Nicotine</td>
<td>1</td>
<td>1 Drop</td>
</tr>
<tr>
<td>TCDD</td>
<td>0.001</td>
<td>Less Than 1 Drop</td>
</tr>
<tr>
<td>Botulinus toxin</td>
<td>0.00001</td>
<td>Less Than 1 Drop</td>
</tr>
<tr>
<td></td>
<td>Teratogenicity</td>
<td>Mutagenicity</td>
</tr>
<tr>
<td>----------------</td>
<td>---------------</td>
<td>--------------</td>
</tr>
<tr>
<td>1. Insidious Nature</td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Cause is Mild</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Relative to the Effect)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>2. Duration and Time</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Between Cause and Effect</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Weeks</td>
<td>Generations</td>
<td>Years</td>
</tr>
<tr>
<td>3. Irreversible</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>4. Greater Susceptibility</td>
<td></td>
<td></td>
</tr>
<tr>
<td>of Immature Tissues</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Yes</td>
<td>No</td>
<td>Yes/No</td>
</tr>
<tr>
<td>5. Differences</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered Development at Tissue/Organ Level</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Altered Nucleotide Sequence-Molecular Level: DNA</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Uncontrolled Proliferation at Cellular Level</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
EPA Weight-of-Evidence Classification System

Group A. Human Carcinogen -- indicates that there is sufficient evidence from epidemiological studies to support a cause-effect relationship between substance and cancer.

Group B. Probable Human Carcinogen --
B₁: classified on the basis of sufficient evidence from animal studies and limited epidemiological evidence
B₂: classified on the basis of sufficient evidence from animal studies and epidemiological data that is inadequate or non-existent.
Group C. Possible Human Carcinogen - indicates that there is limited evidence from animal studies and no epidemiological data

Group D. Not Classifiable as to Human Carcinogenicity - data from human epidemiological and animals studies are inadequate or completely lacking, so no assessment as to the substance’s cancer-causing hazard is possible.
• What concentration of chemicals in air, water, soil, food, consumer products are safe?
• Chemicals produce specific effects and these are dose related.
Problem Statement

- Acceptable risk levels
- Public alarmist reaction to any risk
- Placing risk in perspective
Types of Risk Assessments

- **Linear**: Used to portray the risk of carcinogenicity
- **Threshold**: Used to model all other forms of toxicity
\[ R = T \times E \]

Risk = Toxicity \times Exposure

where

\[ T = \text{toxicity of a specific chemical} \]

\[ E = \text{amount of exposure a population has to a specified chemical} \]
Routes of Exposure

I q j h v w r q  G h u p d e #  I q k d d w r q
The Difference Between Exposure and Dose

• Dose = The amount of a chemical in the body
Cleans Water Act (CWA) & Safe Drinking Water Act (SDWA)

• The Safe Drinking Water Act (SDWA) was originally passed by Congress in 1974 to protect public health by regulating the nation's public drinking water supply.

• The law was amended in 1986 and 1996 and requires many actions to protect drinking water and its sources: rivers, lakes, reservoirs, springs, and ground water wells.
SDWA

• SDWA authorizes the EPA to set national health-based standards for drinking water to protect against both naturally-occurring and man-made contaminants that may be found in drinking water.
National Primary Drinking Water Regulations

• **Maximum Contaminant Level (MCL) -**
The highest level of a contaminant that is allowed in drinking water. MCLs are set as close to MCLGs as feasible using the best available treatment technology and taking cost into consideration. MCLs are enforceable standards.
National Primary Drinking Water Regulations

• **Maximum Contaminant Level Goal (MCLG)** - The level of a contaminant in drinking water below which there is no known or expected risk to health. MCLGs allow for a margin of safety and are non-enforceable public health goals.
National Primary Drinking Water Regulations

- **Maximum Residual Disinfectant Level (MRDL)** - The highest level of a disinfectant allowed in drinking water. There is convincing evidence that addition of a disinfectant is necessary for control of microbial contaminants.
National Primary Drinking Water Regulations

• **Maximum Residual Disinfectant Level Goal (MRDLG)** - The level of a drinking water disinfectant below which there is no known or expected risk to health. MRDLGs do not reflect the benefits of the use of disinfectants to control microbial contaminants.
# National Primary Drinking Water Regulations

<table>
<thead>
<tr>
<th>Chemical</th>
<th>MCL (mg/L)</th>
<th>MCLG (mg/L)</th>
<th>MRDL (mg/L)</th>
<th>MRDLG (mg/L)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenic</td>
<td>0</td>
<td>0.01</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Lead</td>
<td>0</td>
<td>0.015 (Action Level)</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Mercury (inorganic)</td>
<td>0.002</td>
<td>0.002</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>2,4-D</td>
<td>0.07</td>
<td>0.07</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Vinyl chloride</td>
<td>0</td>
<td>0.002</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Chlorine</td>
<td>-</td>
<td>-</td>
<td>4</td>
<td>4</td>
</tr>
</tbody>
</table>
Clean Air Act (CAA)

• The Clean Air Act requires EPA to regulate emissions of toxic air emissions from a published list of industrial sources referred to as "source categories."

• As required under the CAA, the EPA is required to develop regulations for all industries that emit one or more of the pollutants in significant quantities.
# National Ambient Air Quality Standards (NAAQS)

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Primary Standards</th>
<th>Averaging Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Carbon Monoxide</td>
<td>9 ppm</td>
<td>8 Hours</td>
</tr>
<tr>
<td></td>
<td>35 ppm</td>
<td>1 Hours</td>
</tr>
<tr>
<td>Lead</td>
<td>1.5 µg/m³</td>
<td>Quarterly Average</td>
</tr>
<tr>
<td>Nitrogen Dioxide</td>
<td>0.053 ppm</td>
<td>Annual</td>
</tr>
<tr>
<td>Particulate Matter (PM$_{10}$)</td>
<td>50 µg/m³</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>150 µg/m³</td>
<td>24 hours</td>
</tr>
<tr>
<td>Particulate Matter (PM$_{2.5}$)</td>
<td>15 µg/m³</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>65 µg/m³</td>
<td>24 hours</td>
</tr>
<tr>
<td>Ozone</td>
<td>0.08 ppm</td>
<td>8 hours</td>
</tr>
<tr>
<td>Sulfur Oxides</td>
<td>0.03 ppm</td>
<td>Annual</td>
</tr>
<tr>
<td></td>
<td>0.14 ppm</td>
<td>24 hours</td>
</tr>
</tbody>
</table>
Pesticides

• Pesticides are widely used in producing food. These pesticides may remain in small amounts (called residues) in or on fruits, vegetables, grains, and other foods.

• To ensure the safety of the food supply, EPA regulates the amount of each pesticide that may remain in and on foods.

• The levels of residues allowed by EPA to remain in or on food are known as tolerances.
Pesticides

• In setting the tolerance, EPA must make a safety finding that the pesticide can be used with "reasonable certainty of no harm."

• To make this finding, EPA considers:

  1. the toxicity of the pesticide and its break-down products
  2. how much of the pesticide is applied and how often
  3. how much of the pesticide (i.e., the residue) remains in or on food by the time it is marketed and prepared
## Pesticides

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Commodity</th>
<th>Concentrations (ppm)</th>
<th>Commodity</th>
<th>Concentrations (ppm)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Captan</td>
<td>Apple</td>
<td>25</td>
<td>Mango</td>
<td>50</td>
</tr>
<tr>
<td>Malathion</td>
<td>Apple</td>
<td>8</td>
<td>Alfalfa</td>
<td>135</td>
</tr>
<tr>
<td>Parathion</td>
<td>Alfalfa</td>
<td>1.25</td>
<td>Wheat</td>
<td>1</td>
</tr>
<tr>
<td>Sulfosulfuron</td>
<td>Cattle</td>
<td>0.005</td>
<td>Hog</td>
<td>0.005</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>Goat</td>
<td>0.01</td>
<td>Milk</td>
<td>0.01</td>
</tr>
</tbody>
</table>
OSHA

• OSHA sets permissible exposure limits (PELs) to protect workers against the health effects of exposure to hazardous substances.
• PELs are regulatory limits on the amount or concentration of a substance in the air. They may also contain a skin designation. PELs are enforceable.
## OSHA PEL

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Standards (8 Hr Time-Weighted Average)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ozone</td>
<td>0.1 ppm</td>
</tr>
<tr>
<td>Xylene</td>
<td>100 ppm</td>
</tr>
<tr>
<td>Carbon Dioxide</td>
<td>5000 ppm</td>
</tr>
<tr>
<td>Mercury</td>
<td>1 mg/ m³</td>
</tr>
<tr>
<td>Asbestos</td>
<td>0.1 fibers/ mL</td>
</tr>
<tr>
<td>Trichloroethylene</td>
<td>100 ppm</td>
</tr>
</tbody>
</table>
Lysol Toilet Bowl Cleaner

- Hydrogen chloride
- 9.5 % HCl
MSDS HCl

HYDROCHLORIC ACID (LESS THAN 10%)

1. Product Identification
   Synonyms: Muriatic acid solution; 10:1 Dilute Hydrochloric acid; Hydrochloric acid volumetric solutions (0.2 - 2.0 N)
   CAS No.: 7647-01-0
   Molecular Weight: 36.46
   Chemical Formula: HCl in water

2. Composition/Information on Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No</th>
<th>Percent</th>
<th>Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Chloride</td>
<td>7647-01-0</td>
<td>0.7 - 8%</td>
<td>Yes</td>
</tr>
<tr>
<td>Water</td>
<td>7732-18-5</td>
<td>92 - 99%</td>
<td>No</td>
</tr>
</tbody>
</table>
3. Hazards Identification

Emergency Overview

DANGER! CORROSIVE. LIQUID AND MIST CAUSE SEVERE BURNS TO ALL BODY TISSUE. MAY BE FATAL IF SWALLOWED OR INHALED.

SAF-T-DATA(tm) Ratings (Provided here for your convenience)

Health Rating: 3 - Severe (Poison)
Flammability Rating: 0 - None
Reactivity Rating: 1 - Slight
Contact Rating: 4 - Extreme (Corrosive)
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES
Storage Color Code: White (Corrosive)

Potential Health Effects

Health hazards given on this data sheet apply to concentrated solutions of hydrochloric acid. Hazards of dilute solutions may be reduced, depending upon the concentration. Degree of hazard for these reduced concentrations is not currently addressed in the available literature.

Inhalation:
Corrosive! Inhalation of vapors can cause coughing, choking, inflammation of the nose, throat, and upper respiratory tract, and in severe cases, pulmonary edema, circulatory failure, and death.

Ingestion:
Corrosive! Swallowing hydrochloric acid can cause immediate pain and burns of the mouth, throat, esophagus and gastrointestinal tract. May cause nausea, vomiting, and diarrhea, and in severe cases, death.

Skin Contact:
Corrosive! Can cause redness, pain, and severe skin burns. Concentrated solutions cause deep ulcers and discolor skin.

Eye Contact:
Corrosive! Vapors are irritating and may cause damage to the eyes. Contact may cause severe burns and permanent eye damage.

Chronic Exposure:
Long-term exposure to concentrated vapors may cause erosion of teeth. Long term exposures seldom occur due to the corrosive properties of the acid.

Aggravation of Pre-existing Conditions:
Persons with pre-existing skin disorders or eye problems or impaired respiratory function may be more susceptible to the effects of the substance.
• **Toxicological Information**

• Hydrochloric acid: Inhalation rat LC50: 3124 ppm/1H; Oral rabbit LD50: 900 mg/kg. Investigated as a tumorigen, mutagen, reproductive effector.

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>NTP Carcinogen---</th>
<th>IARC Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrogen Chloride (7647-01-0)</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Water (7732-18-5)</td>
<td>No</td>
<td>No</td>
</tr>
</tbody>
</table>
Cutex Strengthening Nail Polish Remover

- Acetone
MSDS Acetone

ACETONE

1. Product Identification
   Synonyms: Dimethylketone; 2-propanone; dimethylketal
   CAS No.: 67-64-1
   Molecular Weight: 58.08
   Chemical Formula: (CH₃)₂CO

2. Composition/Information on Ingredients

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>CAS No</th>
<th>Percent</th>
<th>Hazardous</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone</td>
<td>67-64-1</td>
<td>99 - 100%</td>
<td>Yes</td>
</tr>
</tbody>
</table>
3. Hazards Identification

Emergency Overview

DANGER! EXTREMELY FLAMMABLE LIQUID AND VAPOR. VAPOR MAY CAUSE FLASH FIRE. HARMFUL IF SWALLOWED OR INHALED. CAUSES IRRITATION TO SKIN, EYES AND RESPIRATORY TRACT. AFFECTS CENTRAL NERVOUS SYSTEM.

SAF-T-DATA™ Ratings (Provided here for your convenience)

Health Rating: 2 - Moderate
Flammability Rating: 3 - Severe (Flammable)
Reactivity Rating: 0 - None
Contact Rating: 3 - Severe
Lab Protective Equip: GOGGLES & SHIELD; LAB COAT & APRON; VENT HOOD; PROPER GLOVES; CLASS B EXTINGUISHER
Storage Color Code: Red (Flammable)

Potential Health Effects

Inhalation:
Inhalation of vapors irritates the respiratory tract. May cause coughing, dizziness, dullness, and headache. Higher concentrations can produce central nervous system depression, narcosis, and unconsciousness.

Ingestion:
Swallowing small amounts is not likely to produce harmful effects. Ingestion of larger amounts may produce abdominal pain, nausea and vomiting. Aspiration into lungs can produce severe lung damage and is a medical emergency. Other symptoms are expected to parallel inhalation.

Skin Contact:
Irritating due to defatting action on skin. Causes redness, pain, drying and cracking of the skin.

Eye Contact:
Vapors are irritating to the eyes. Splashes may cause severe irritation, with stinging, tearing, redness and pain.

Chronic Exposure:
Prolonged or repeated skin contact may produce severe irritation or dermatitis.

Aggravation of Pre-existing Conditions:
Use of alcoholic beverages enhances toxic effects. Exposure may increase the toxic potential of chlorinated hydrocarbons, such as chloroform, trichloroethane.
4. Toxicological Information

Oral rat LD50: 5800 mg/kg; Inhalation rat LC50: 50,100mg/m3; Irritation eye rabbit, Standard Draize, 20 mg severe; investigated as a tumorigen, mutagen, reproductive effector.

Cancer Lists

---NTP Carcinogen---

<table>
<thead>
<tr>
<th>Ingredient</th>
<th>Known</th>
<th>Anticipated</th>
<th>IARC Category</th>
</tr>
</thead>
<tbody>
<tr>
<td>Acetone (67-64-1)</td>
<td>No</td>
<td>No</td>
<td>None</td>
</tr>
</tbody>
</table>
• Threshold=Dose below which no effect is seen
• NOAEL=No Observable Adverse Effect Level
Chronic Toxicity Threshold/NOAEL

Response %

Dose (mg/kg/day)
Chronic Toxicity
Safety Factor/Reference Dose

Response %

Dose (mg/kg/day)

0 10 50 100 200 500 1,000 5,000 10,000 50,000 1 E+05
Rfd = \textbf{NOAEL} (UF x MF)

Where: UF = Uncertainty Factor

MF = Modifying Factor

Because the threshold dose value is difficult to know for certain, the UF and MF provide a factor of safety that is protective of the public health.
Hazard Quotient = Dose (mg/kg/day) / RfD (mg/kg/day)
Generalized Hazard Quotient Equation

\[
\text{Hazard Quotient} = \frac{\text{CC} \times \text{CR} \times \text{CF} \times \text{EF} \times \text{ED}}{\text{BW} \times \text{AT}}
\]

- **RfD**: reference dose
- **CC**: conc. of contaminants
- **CR**: contact rate
- **CF**: conversion factor
- **ED**: exposure duration
- **EX**: exposure frequency
- **AT**: averaging time
- **BW**: body weight
• If the hazard quotient is greater than one (a person is exposed to more of the substance than is acceptable under public policy), there is a POSSIBILITY that a health effect may occur.
Hazard Index

• Calculated as sum of hazard quotients
• Hazard Index=Sum of Hazard Quotients (individual organ or system)
• Used when potential exists for exposure to more than one substance that may affect a specific target organ system
Dose Response for Carcinogens

Response %

Dose (mg/kg/day)

Lowest Dose Given
Dose Response for Carcinogens

Extrapolated line from the smallest dose known to cause and effect to zero
Risk = CSF•CC•CR•CF•EF•ED
          
          BW•AT

CSF: cancer slope factor
CC: conc. of contaminants
CR: contact rate
ED: exposure duration

EF: exposure frequency
CF: conversion factor
AT: averaging time
BW: body weight
“It should be emphasized that the linearized multistage procedure leads to a plausible upper limit to the risk that is consistent with some mechanism of carcinogenesis. Such an estimate, however, does not necessarily give a realistic prediction of the risk. The true value of the risk is unknown and may be as low as zero”

U.S. Environmental Protection Agency 1980
Risk and Regulation

• Government agencies use risk assessment to protect the population.
• Different agencies use different methods and assumptions when determining risk.
• As a result “safe” exposures often vary from agency to agency.
Absorption Distribution
Metabolism Excretion

Absorption into gastrointestinal tract, lungs, and through the skin

Distribution from blood stream to rest of body, including fat, brain, liver

Metabolism $X \xrightarrow{\text{enzymes}} Y$

$x = \text{absorbed, distributed chemical}$

$y = \text{metabolite}$

Excretion via exhaled breath; from liver through bile/feces; from kidneys through urine
## Biological Half-Life

<table>
<thead>
<tr>
<th>Chemicals</th>
<th>Half-Life</th>
</tr>
</thead>
<tbody>
<tr>
<td>(in humans unless otherwise noted)</td>
<td></td>
</tr>
<tr>
<td>Benzene</td>
<td>1- 3 hours</td>
</tr>
<tr>
<td>Cadmium</td>
<td>10-30 years</td>
</tr>
<tr>
<td>Caffeine</td>
<td>3.5 hours</td>
</tr>
<tr>
<td>Ethanol</td>
<td>2-4 hours</td>
</tr>
<tr>
<td>Toluene</td>
<td>72 hours (whole blood)</td>
</tr>
<tr>
<td>Ethylbenzene</td>
<td>4-7 hours (for metabolite)</td>
</tr>
<tr>
<td>Xylene</td>
<td>20-30 hours</td>
</tr>
<tr>
<td>Tetrachlorethylene</td>
<td>33-72 hours</td>
</tr>
</tbody>
</table>
Medical Evaluation of Possible Exposures to Environmental Chemicals

Exposure → Dose → Health Effects

<table>
<thead>
<tr>
<th>Environmental Testing</th>
<th>Biological Testing</th>
<th>Medical Testing</th>
</tr>
</thead>
<tbody>
<tr>
<td>a) Air</td>
<td>a) Blood</td>
<td>a) History</td>
</tr>
<tr>
<td>b) Water</td>
<td>b) Urine</td>
<td>b) Physical Exam.</td>
</tr>
<tr>
<td>c) Soil</td>
<td>c) Breath</td>
<td>c) Laboratory</td>
</tr>
<tr>
<td>d) Food</td>
<td>d) Tissue</td>
<td>d) Radiology</td>
</tr>
</tbody>
</table>
Blood Acetone (mg/L)

<table>
<thead>
<tr>
<th>Condition</th>
<th>mg/L</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Non-exposed</td>
<td></td>
</tr>
<tr>
<td>Median Non-exposed</td>
<td></td>
</tr>
<tr>
<td>Min. Ketoacidosis</td>
<td></td>
</tr>
<tr>
<td>Max. Ketoacidosis</td>
<td></td>
</tr>
<tr>
<td>2 hr. @ 100 ppm</td>
<td></td>
</tr>
<tr>
<td>2 hr. @ 500 ppm</td>
<td></td>
</tr>
<tr>
<td>8 hr. @ 142 ppm</td>
<td></td>
</tr>
<tr>
<td>8 hr. @ 2100 ppm</td>
<td></td>
</tr>
<tr>
<td>No Intoxication</td>
<td></td>
</tr>
</tbody>
</table>

Graph showing acetone levels under various conditions.
Asbestos Hazards Found in Your Automobile

- Electrical Switchboard
- Electronic Motor Components
- Automatic Transmission Friction Components
- Radiator Sealant
- Clutch Facings
- Automotive Mufflers
- Transmission
- Brake Lining and Brake Pads
- Gasket Materials
- Automotive Body Filler
“The Savior of Mankind”

*DDT* called the “Savior of Mankind” because it controlled the fleas and louse that transmitted typhus.

*World War II was the first war in which casualties eclipsed deaths due to disease and pestilence.*

*Xenopsylla cheopsis, flea*

*Pediculus humanus, human body louse*
…On Second Thought!!

- Production increased four-fold from 1945 to 1955.
- Widespread use in public areas and the backyards of America.
- **1946** - 1st report of fatty tissue accumulation.
- **1958** - Dutch elm disease and dead robins.
- **1962** - Rachel Carson makes fateful prediction.
The Unforeseen Effects of DDT

- DDT remains effective for years. An initial selling point to farmers and the U.S. Public Health Service.
- Bioconcentration up the food chain.
- The rise of secondary pests - spider mites.
In the Absence of DDT …

Malaria cases and fatalities are on the rise. Up to 3,000,000 people succumb to malaria every year.
Development of Risk Analysis

• Risk analysis is the process of reviewing information on a hazard to characterize that hazard’s impact on human health.

• Risk analysis allows public groups to make informed decisions and weigh the risks and benefits in their community.
The Process of Risk Analysis

- A review of scientific studies
- An understanding of the properties of a risk,
- An assessment of levels of human exposure and dose
- A conclusion about the likelihood, impact and extent of a risk.
Tools of Risk Analysis

- Risk analysis employs several scientific disciplines in its goal to characterize a risk.
Tools of Risk Analysis

• Toxicology
  – Toxicologists study chemicals to determine their physiological and health impacts on humans.
  – Regulatory toxicology aims at guarding the public from dangerous chemical exposures.
Extrapolation

• In risk analysis, the term extrapolation refers to the use of animal data to predict human response to chemical exposure.
Extrapolation

• The results from high-dose, short duration studies are used to extrapolate human response to the longer term, lower level exposures we generally receive.
Structures

- Butadiene
- Butadiene Monoepoxide
- Benzene
- Benzene Oxide
- Styrene
- Styrene Oxide
Butadiene Metabolism
The Process of Risk Analysis

• The process of risk analysis has four steps;
  – hazard identification;
  – dose-response evaluation;
  – exposure assessment; and
  – risk characterization.
Hazard Identification

• The initial step in risk analysis, hazard identification, involves identifying chemicals that present a risk to human health.

• This step entails performing a qualitative assessment of a chemical’s potential for negative health impacts on humans.
Dose-Response Assessment

• The next step, dose-response evaluation, provides a quantitative view of the risk.
• This step also involves a review of scientific studies and data.
• In this case, the magnitude of response is correlated with the dose.
Exposure Assessment

• The purpose of the exposure assessment is to measure or estimate a person’s level of exposure.

• Exposure is different from dose in that exposure refers to the amount of a substance in the environment, while dose is the level of a substance actually taken into the body.
Exposure Assessment

• Dose can be influenced by many factors, such as how the substance enters the body, whether absorbed through the skin, ingested with food, or inhaled.
Risk Characterization

- Risk characterization provides a picture of the risk that addresses its severity, likelihood, and consequences.
- The risk characterization includes an estimate of the negative effects to exposed individuals, such as the number of cases of cancer or deaths per million people.
Limitations of Risk Analysis

- Limitations of risk analysis include uncertainty, variability, and effect of multiple exposures.
- Despite these limitations, risk assessment is still a valuable tool for protecting public health.
Risk Management

- Risk management involves merging the results of risk analysis with various social factors, such as socioeconomic conditions, political pressures, and economic concerns.
Risk Management

• Three procedures for risk management are:
  – educational;
  – economic; and
  – regulatory
Risk Management

• Risk management generally involves comparing the risk to some other factor such as the cost, or reducing the risk or the benefit gained from the risk.
Risk Management

• The “best” course of action is not always the one that reduces the most risk, but rather, is the most economically feasible option, reducing the greatest amount of risk per dollar spent.
Risk Communication

- The goal of risk communication is to effectively relay risk information developed through risk analysis to various interested groups.
Risk Communication

• Methods of risk communication include public hearings, emergency hotlines, information pamphlets.
Risk Communication

- Risk communication can be challenging, as it requires addressing people’s different risk perceptions, biases, scientific knowledge, educational backgrounds, even race and gender.
Risk Communication

• Translating technical terminology into comprehensible terminology can increase the effectiveness of risk communication.
One in a billion ($1 \times 10^{-9}$)

| TIME:       | One second in 6.4 months. |
| LENGTH:    | 1.56 inches in 25,000 miles (the circumference of the earth at the equator). |
| AREA:      | One sq. yard in 324 square miles. |
| VOLUME:    | Approximately a half drop of water in a 17,000 gallon pool. |
| WEIGHT:    | A particle of dust ($<0.01$ grams) on a 2,000 pound automobile. |
Risk of drowning in the bathtub per year: 1.50E-06

Risk of a U.S. resident being struck by a crashing airplane: 4.00E-06

Risk of cancer death from living in Denver compared to New York: 1.00E-05

Risk of cancer death from eating one peanut butter sandwich per day for 1 year: 1.00E-05

Risk of cancer death from drinking 1 light beer per day for 1 year: 2.00E-05

Risk of being struck by lightning: 1.10E-04

Risk of death from home accidents in one year: 1.10E-04
1. Risk of drowning in the bathtub per year: 1.50E-06

2. Risk of a U.S. resident being struck by a crashing airplane: 4.00E-06

3. Risk of cancer death from living in Denver compared to New York: 1.00E-05
Risk of cancer death from eating one peanut butter sandwich per day for 1 year

Risk of cancer death from drinking 1 light beer per day for 1 year

Risk of being struck by lightning

Risk of death from home accidents in one year
Estimated Cancer Risk from Ambient Formaldehyde in Broward County

Estimated Cancer Risk from Ambient Benzene in Broward County

Risk Probability
1.50E-06

Risk of drowning in the bathtub per year

4.00E-06

Risk of a U.S. resident being struck by a crashing airplane

1.00E-05

Risk of cancer death from living in Denver compared to New York

1.00E-05

Risk of cancer death from eating one peanut butter sandwich per day for 1 year

1.00E-05

Risk of cancer death from drinking 1 light beer per day for 1 year

Risk of being struck by lightning

1.00E-05

Estimated Cancer Risk from Ambient Benzene in Broward County

1.00E-05

Estimated Cancer Risk from Ambient Formaldehyde in Broward County

2.00E-05

Risk Probability
# Food-Related Risks

<table>
<thead>
<tr>
<th>Risk</th>
<th>Average Lifetime Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eating one tablespoon of Peanut butter per day</td>
<td>1.4x10^{-4}</td>
</tr>
<tr>
<td>Drinking one pint of milk per day</td>
<td>1.4x10^{-4}</td>
</tr>
<tr>
<td>Eating one-half pound of steak per week</td>
<td>2.1x10^{-5}</td>
</tr>
</tbody>
</table>
### Everyday Cancer Risks

<table>
<thead>
<tr>
<th>Risk</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>All cancers</td>
<td>0.25</td>
</tr>
<tr>
<td>One transcontinental round trip by air per year*</td>
<td>$7 \times 10^{-5}$</td>
</tr>
<tr>
<td>Natural background radiation at sea level</td>
<td>$1.4 \times 10^{-4}$</td>
</tr>
<tr>
<td>Average diagnostic X-ray</td>
<td>$1.4 \times 10^{-4}$</td>
</tr>
<tr>
<td>Smoking</td>
<td>$8.4 \times 10^{-2}$</td>
</tr>
<tr>
<td>Sharing A room with a smoker</td>
<td>$7.0 \times 10^{-4}$</td>
</tr>
</tbody>
</table>

*Estimated based on exposure to cosmic rays

Source: Crouch and Wilson, 1982
Estimated Average Annual and Average Lifetime Risks of Death for United States Residents from Specific Incidents

<table>
<thead>
<tr>
<th>Incident</th>
<th>Average Annual Risk</th>
<th>Average Lifetime Risk</th>
</tr>
</thead>
<tbody>
<tr>
<td>Motor vehicle accident</td>
<td>$2.4 \times 10^{-4}$</td>
<td>$1.7 \times 10^{-2}$</td>
</tr>
<tr>
<td>Falls</td>
<td>$6.2 \times 10^{-5}$</td>
<td>$4.3 \times 10^{-3}$</td>
</tr>
<tr>
<td>Drowning</td>
<td>$3.6 \times 10^{-5}$</td>
<td>$2.5 \times 10^{-3}$</td>
</tr>
<tr>
<td>Fires</td>
<td>$2.8 \times 10^{-5}$</td>
<td>$1.7 \times 10^{-3}$</td>
</tr>
<tr>
<td>Firearms</td>
<td>$1.0 \times 10^{-5}$</td>
<td>$7.0 \times 10^{-4}$</td>
</tr>
<tr>
<td>Electrocution</td>
<td>$5.3 \times 10^{-6}$</td>
<td>$3.9 \times 10^{-4}$</td>
</tr>
<tr>
<td>Floods</td>
<td>$6.0 \times 10^{-7}$</td>
<td>$4.2 \times 10^{-5}$</td>
</tr>
<tr>
<td>Lightning</td>
<td>$5.0 \times 10^{-7}$</td>
<td>$3.5 \times 10^{-5}$</td>
</tr>
<tr>
<td>Animal bite or sting</td>
<td>$2.4 \times 10^{-7}$</td>
<td>$1.7 \times 10^{-5}$</td>
</tr>
</tbody>
</table>

Source: Crouch and Wilson, 1982
Regulations Protect

They Do Not Predict
Carcinogens Released to the Atmosphere in the Houston/Galveston Area in 1993

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Air Releases (pounds)</th>
<th>Carcinogen Class</th>
</tr>
</thead>
<tbody>
<tr>
<td>Benzene</td>
<td>5,742,735</td>
<td>A</td>
</tr>
<tr>
<td>1,3-Butadiene</td>
<td>2,578,446</td>
<td>B2</td>
</tr>
<tr>
<td>Chloroform</td>
<td>2,153,571</td>
<td>B2</td>
</tr>
<tr>
<td>Vinyle Chloride</td>
<td>385,515</td>
<td>A</td>
</tr>
<tr>
<td>Arylonitrile</td>
<td>207,513</td>
<td>B1</td>
</tr>
</tbody>
</table>
Individual Risk

• Distinguishes Individual Differences (e.g., Age, Gender, Weight, Lifestyle)
Methods of Risk Calculation

• Individual-specific data (hypothetical or actual)
• U.S. mortality statistics
• Epidemiological data
Individual Risk Evaluation

<table>
<thead>
<tr>
<th>Condition</th>
<th>Risk Comparison</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stroke</td>
<td>1/1,000 vs. 9/1,000</td>
</tr>
<tr>
<td>Esophageal Cancer</td>
<td>1/1,000 vs. 3/1,000</td>
</tr>
<tr>
<td>Heart Attack</td>
<td>1/1,000 vs. 69/1,000</td>
</tr>
<tr>
<td>Lung Cancer</td>
<td>1/1,000 vs. 12/1,000</td>
</tr>
<tr>
<td>Liver Cirrhosis</td>
<td>1/1,000 vs. 2/1,000</td>
</tr>
<tr>
<td>Kidney Failure</td>
<td>1/1,000 vs. 2/1,000</td>
</tr>
<tr>
<td>Diabetes Mellitus</td>
<td>1/1,000 vs. 22/1,000</td>
</tr>
</tbody>
</table>

Conclusion: Lifestyle risks far outweigh risks from environmental/clinical exposure.

Exemplary 45-Year-Old Male
- Fit, normo-tensive, non-diabetic, non-smoker, non-drinker, normal body weight.
- Risk of death from all causes in next 10 years - 3.8 % (3.8 x 10^{-2})

45-Year-Old Male
- Morbidly obese, hypertension, diabetic, smoker, drinker, sedentary.
- Risk of death from all causes in next 10 years - 16.3 % (1.63 x 10^{-1})
Comparison of Risk of Death

Chances in 1,000,000

- EPA Acceptable
- Exemplary 45-Year-Old
- Population
- Male

Risk
Contributory Risk

- Qualitative characterization of contributory risk
- Need to account for direct and indirect sources of risk in an assessment
- Voluntary actions (such as buying a jet ski, RV or snowmobile) contribute to involuntary risk in others
Contributory Risk

A car is bought → The car maker released toxics while making the car → The car maker’s suppliers released toxics in making components → The suppliers to the suppliers released toxics

Glass
Filaments
Plastics

Lights
Wheels
Seatbelts

Total Toxic Emissions = Direct Emissions & Indirect Emissions
Bioterrorism Risks
THEN

What? Me worry?
About what?
Now

Me? I’m afraid.

Of what?
Well, just about everything—
Mail, flying, food…
Brentwood

Trenton

Indianapolis
Risk Related Questions

• **Who** receives antibiotics?
• **Which** antibiotics?
• **What** remedial actions?
• **When** can buildings be reoccupied?
• **How** do we communicate to the public?
Data Considerations

• Infectious dose
• Antibiotic resistance
• Symptoms of infection
• Background levels
• Size of particles
Approximately $1 million in computers and equipment that originated in Trenton, Brentwood, or West Palm Beach tested clean after decon, but due to perception and uncertainty, were slated for disposal.
Satellite image, looking south over the site of the collapsed World Trade Center towers.
Risk Related Materials

- Arsenic
- Asbestos
- Lead
- Mercury
- Nickel
- Organic Chems
- Silica
- Sulfates
- Titanium
- Vanadium

Mold
Risk Related Questions

• Are residences safe?
• Are offices safe?
• Is evacuation needed?
• Is clean-up needed?
• When can we return?