Updated: 25 October 2019

Print version

CEE 370 Environmental Engineering Principles

Lecture #18

Risk: Perception, Assessment, Management

Reading: Mihelcic & Zimmerman, Chapter 6

Reading: Mihelcic, Chapt 4.3.3

Reading: Davis & Masten, Chapter 6

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Basis for Setting Standards

- Experimentation
  - animal testing, human exposure
- Attainability
  - economic & technical feasibility
- Established practice
- Risk Assessment

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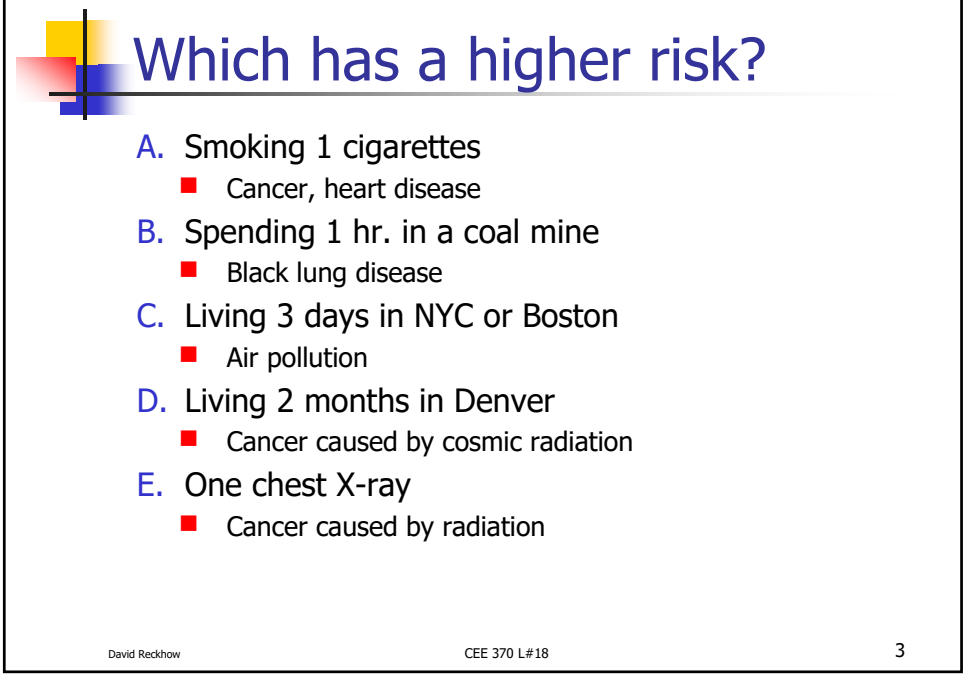
Which has a higher risk?
A. Smoking 1 cigarettes
Cancer, heart disease
B. Spending 1 hr. in a coal mine
Black lung disease
C. Living 3 days in NYC or Boston
Air pollution
D. Living 2 months in Denver
Cancer caused by cosmic radiation
E. One chest X-ray
Cancer caused by radiation
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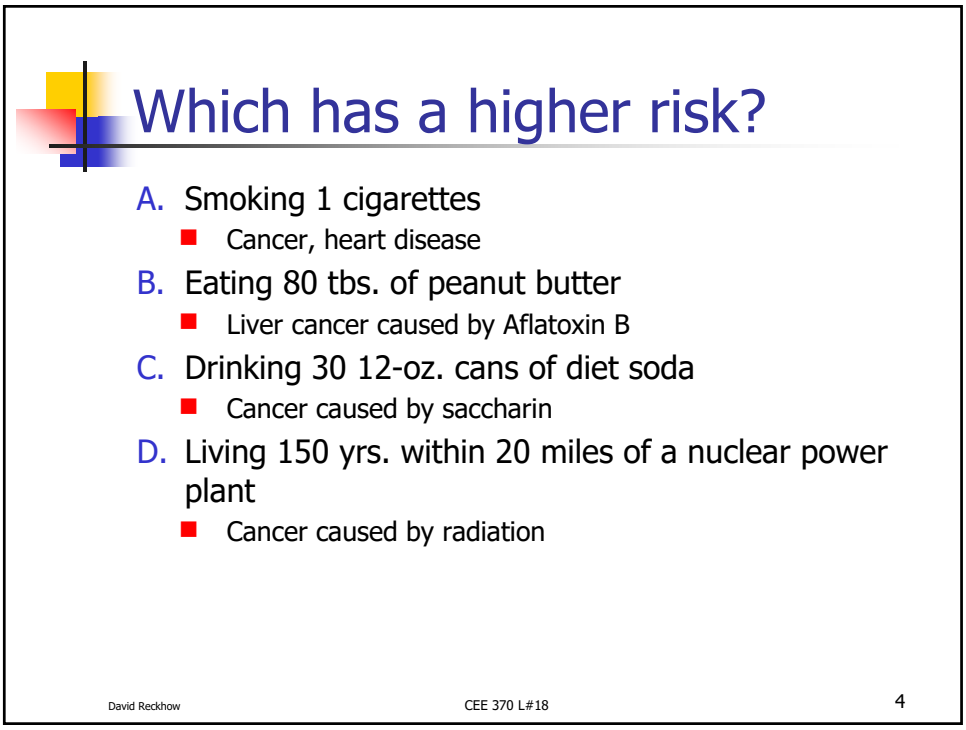
Which has a higher risk?
A. Smoking 1 cigarettes
Cancer, heart disease
B. Eating 80 tbs. of peanut butter
Liver cancer caused by Aflatoxin B
C. Drinking 30 12-oz. cans of diet soda
Cancer caused by saccharin
D. Living 150 yrs. within 20 miles of a nuclear power plant
Cancer caused by radiation
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Risk Perception

All increase chance of death in any year by 0.000001

Smoking 1.4 cigarettes	Cancer, heart disease
Spending 1 hr. in a coal mine	Black lung disease
Living 2 days in NYC or Boston	Air pollution
Living 2 months in Denver	Cancer caused by cosmic radiation
One chest X-ray	Cancer caused by radiation
Eating 40 tbs. of peanut butter	Liver cancer caused by Aflatoxin B
Drinking 30 12-oz. cans of diet soda	Cancer caused by saccharin
Living 150 yrs. within 20 miles of a nuclear power plant	Cancer caused by radiation

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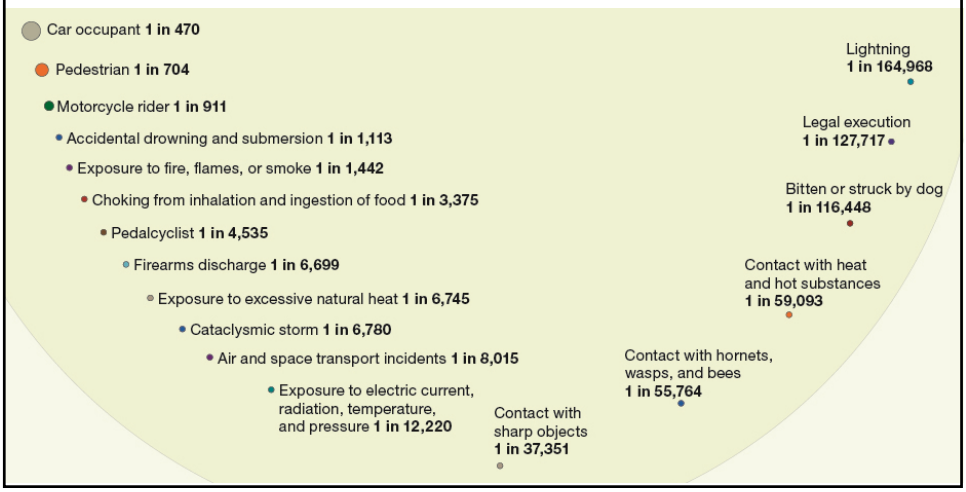
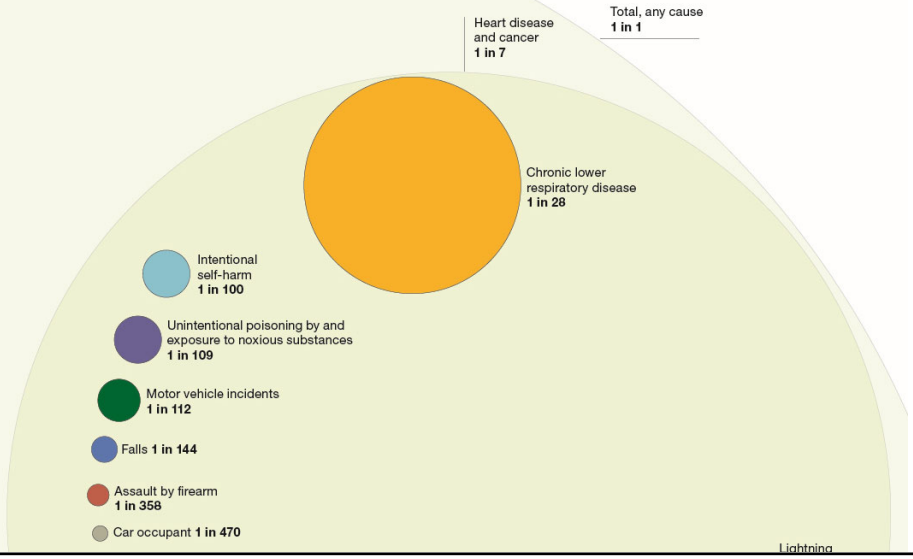
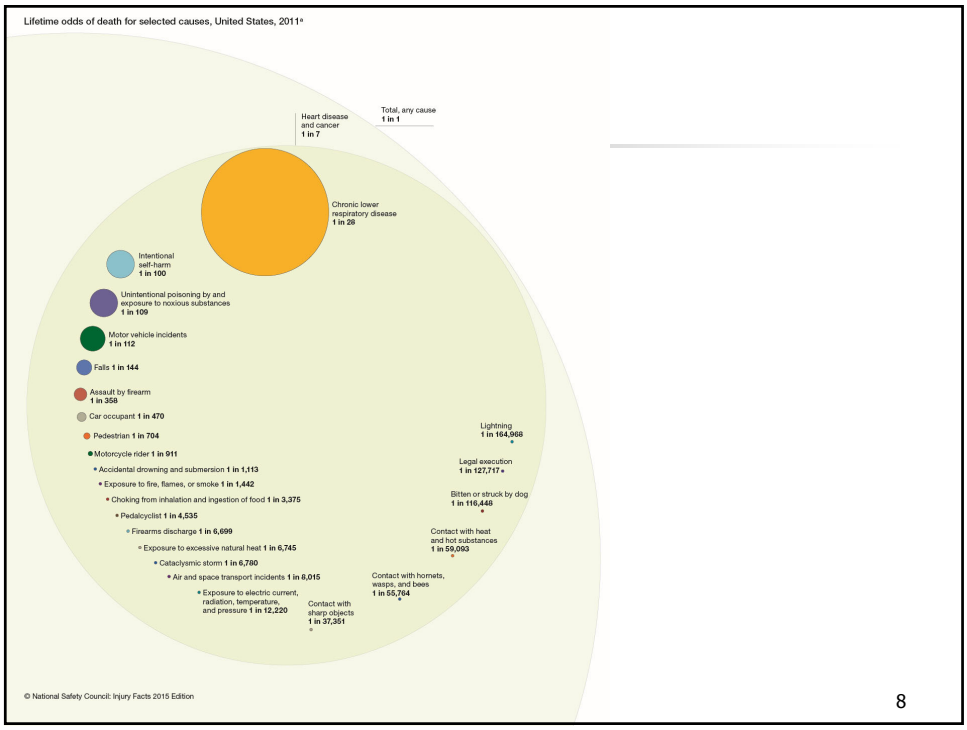
Lifetime odds of death



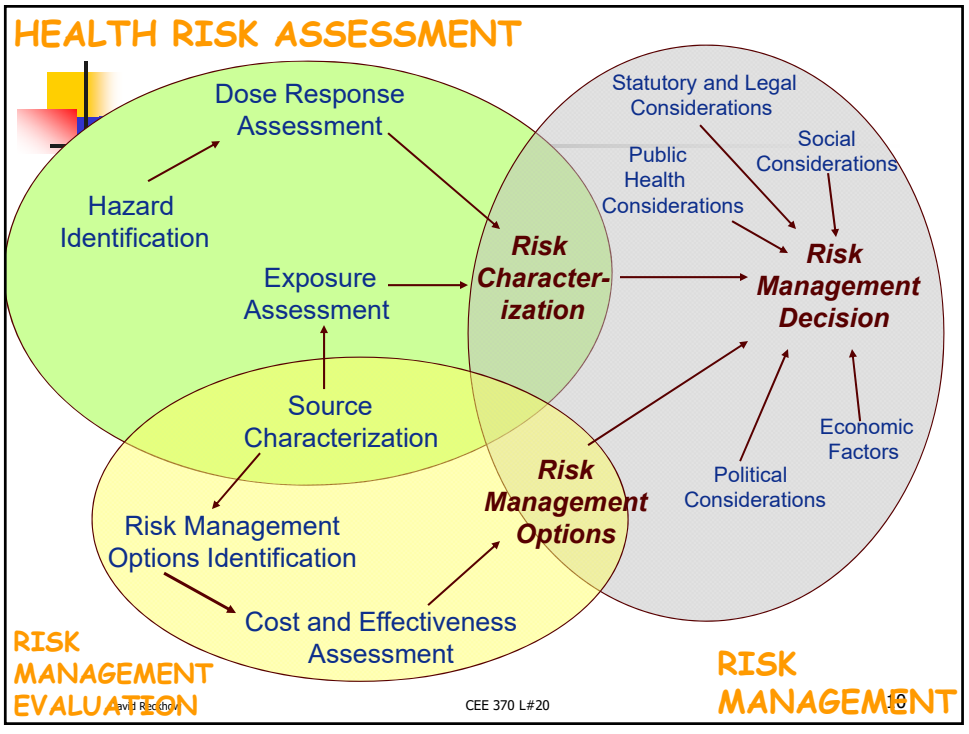
Lifetime odds of death





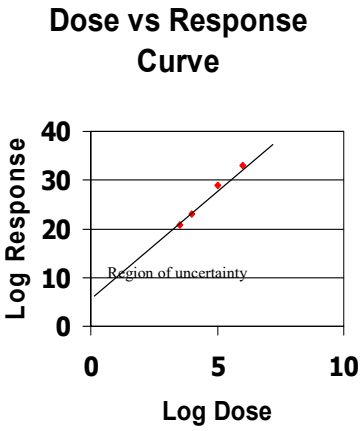
Definitions

- Risk: the probability of occurrence of adverse health effects in humans
  - Risk Assessment: the process of characterizing the nature and probability of adverse health effects of human exposure to environmental hazards
  - Risk Management: the process of evaluating and selecting among alternative regulatory actions
  - Risk Perception: human judgement regarding relative risks: perceived likelihood & severity
  - Risk Communication:



Four steps in a Risk Assessment

- Hazard Identification
  - what is it?
- Dose Response
  - see graph
- Human Exposure
  - actual doses and routes
- Risk Characterization



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Environmental Risk Analysis

Fields of Analysis

Risk Assessment

- Nature of effects
- Potency of agent
- Exposure
- Population at risk
  - Average risk
  - High-end risk
  - Sensitive groups
- Uncertainties of science
- Uncertainties of analysis

Identify
Describe
Measure

Risk Management

- Social importance of risk
- De minimis or acceptable risk
- Reduce/not reduce risk
- Stringency of reduction
- Economics
- Priority of concern
- Legislative mandates
- Legal issues
- Risk perception

Evaluate
Decide
Implement

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THE NEW YORK TIMES **INTERNATIONAL** SUNDAY, OCTOBER 20, 2019

https://www.nytimes.com/2019/10/19/world/americas/venezuela-water.html

Cutbacks, Disrepair and Bacteria Plague Venezuela's Water System

New Tests Expose Health Hazards

By ANATOLY KURMANAEV and ISAYEN HERRERA

The brick shack on the outskirts of Venezuela's capital is crowded with tubs, jugs and buckets. The water they hold must last the family of eight for a week — but it's not enough for frequent washing or flushing, so the kitchen is filled with greasy pots and the house smells of stale urine.

And none of the water is treated, making diarrhea and vomit a regular occurrence.

"We practically live in the bathroom," said the mother of the family, Yarelis Pinto. Her pregnant daughter, Yarielys, sat nearby, pale and listless, recovering from her latest bout of diarrhea just one month away from childbirth.

In Venezuela, a crumbling economy and the collapse of even basic state infrastructure means water comes irregularly — and drinking [illegible] increasingly risky [illegible]. Venezuela's current rate of infant mortality from diarrhea, which is closely related to water quality, is six times higher than 15 years ago, according to the World Health Organization.

But the government stopped releasing official public health data years ago.

So The New York Times commissioned researchers from the Universidad Central de Venezuela to recreate the water quality study they had conducted regularly for the water utility in Caracas from 1992 until 1999.

The scientists found that about a million residents were exposed to contaminated supplies. This puts them at risk of contracting waterborne viruses that could sicken them and threatens the lives of children and the most vulnerable.

"This is a potential epidemic," [illegible] David Reckhow

Fetching water from a mountainside in the Venezuelan capital, Caracas. Left, aid workers distributing supplies in April. A study found widespread contamination in the country's water system.

of pipelines.

The system was part of a broad investment in public infrastructure. The city's piped cooking gas, its glitzy metro sprinkled with avant-garde art, its elevated motorways and its skyscrapers of public housing were examples of modernity in the neglected and volatile continent.

But while the rest of South America made dramatic improvements in drinking water access in [illegible] decades, Venezuela's [illegible] instead hollowed

by The Times showed the main water supply system, which provides about 60 percent of the capital's water, was especially compromised. More than half of the samples taken from the main water system had insufficient chlorine; almost two thirds of the samples had levels of bacteria that exceeded regulations.

Venezuelan authorities have not published any public health data since at least 2017. But survey-based evidence collected by local health advocacy groups

water flowed for two days in September for the first time in six months. It came out dark with sludge that accumulated in the empty pipes.

The study found excessive bacteria in most of the sampled alternative water sources used by Caracas residents, such as mountainside springs, water sold in shops and water cisterns.

Ms. Pinto, the mother of five who lives in the San Isidro shantytown, bought water she thought was safer until 2017. She can no longer afford to, as she has no income and survives on the food her ex-husband brings for their children.

When Ms. Pinto's tubs run dry, her family trudges to a nearby creek with jugs to fill. More fortunate neighbors pay for access to a homemade system made up of miles of interconnected hoses that carry water from a nearby hill.

"When I drink the water, I feel repulsion," said Ms. Pinto.

Her five children are often laid low by vomiting and diarrhea, and the frequent bouts of illness make it hard for the adults to hold jobs. Only one of the four adults in the house worked, earning $8 a month cleaning floors.

But they have no choice, she said. "We have to consume what we have."

The study's researchers say the high bacteria levels in the samples are most likely caused by insufficient chlorine and the unstable supply. These problems have been caused by chronic lack of maintenance, mismanagement and the economic downturn, they say.

The economic crisis has shut down Venezuela's only chlorine plant for months at a time, said a manager at the plant, who spoke on condition of anonymity for fear of reprisals. And frequent electrical outages allow bacteria to accumulate in empty pipes, say the utility's managers.

Several of the study's worst results came out better when new samples were collected and tested again several weeks [illegible] imply-

Toxicity Testing

- Lethal Dose
- Lethal Concentration
  - For aquatic species

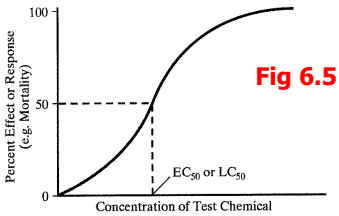


Fig 6.5

Figure 5-41. Typical form of a dose-response curve used values for various chemicals and test organisms.

Table 6.7

Table 5-8. Oral LD_{50} Values for Various Organisms and Chemicals

Chemical	Organism	LD_{50} (mg/kg)
Methyl ethyl ketone	Rat	5,500
Fluoranthene	Rat	2,000
Pyrene	Rat	800
Pentachlorophenol	Mouse	117
Lindane	Mouse	86
Dieldrin	Mouse	38
Sarin (nerve gas)	Rat	0.5

Values from Patnaik, 1992.

Table 6.8

Table 5-9. Forty-eight-hour LC_{50} Values for 2,4-D

Species	LC_{50}, mg/L
Daphnia magna (zooplankton)	25
Fathead minnow	325
Rainbow trout	358

From Patnaik, 1992.

Dose-Response curves

FIGURE 5–2

Hypothetical dose-response curves for two chemical agents (A and B) administered to a uniform population. NOAEL = no observed adverse effect level.

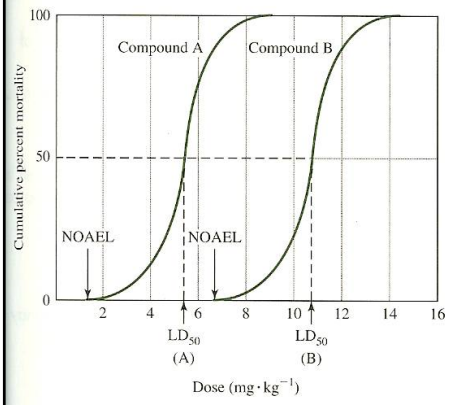
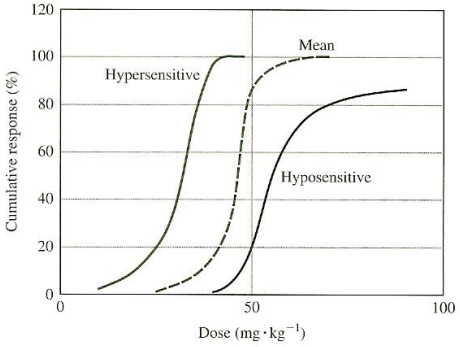


FIGURE 5–3

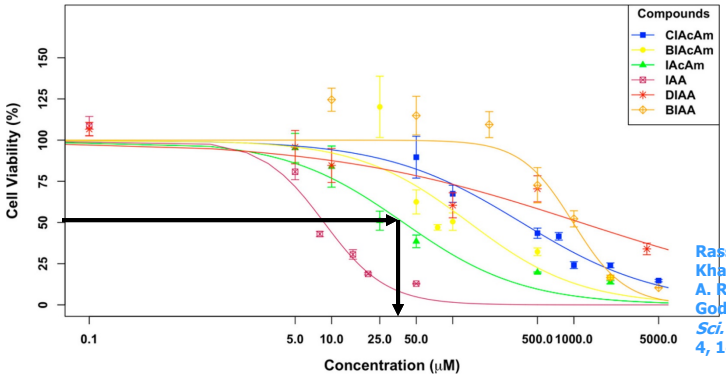
Hypothetical dose-response relationships for a chemical agent administered to a uniform population.



Reverse x-scale

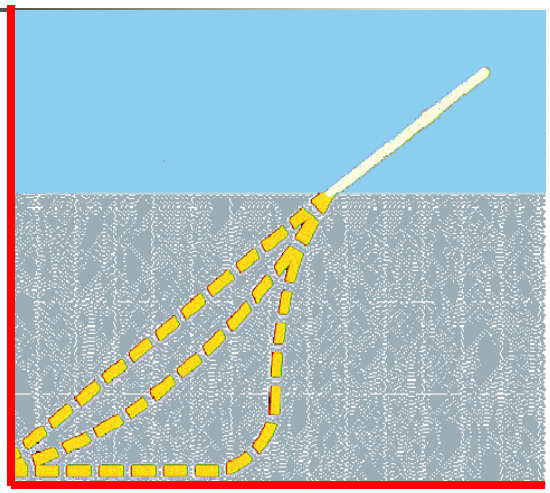
- Toxicity of iodinated compounds in drinking water

Compound	Abbreviation	Molecular structure
Iodoacetic acid	IAA	
Diiodoacetic acid	DIAA	
Bromoiodoacetic acid	BIAA	
Iodoacetamide	IAcAm	
Chloroiodoacetamide	ClAcAm	
Bromoiodoacetamide	BIAcAm	



Rassil Sayess; Ahmed Khalil; Mittal Shah; David A. Reckhow; Krystal J. Godri Pollitt; *Environ. Sci. Technol. Lett.* 2017, 4, 143-148.

Dose-Response Curve



Hazard Identification

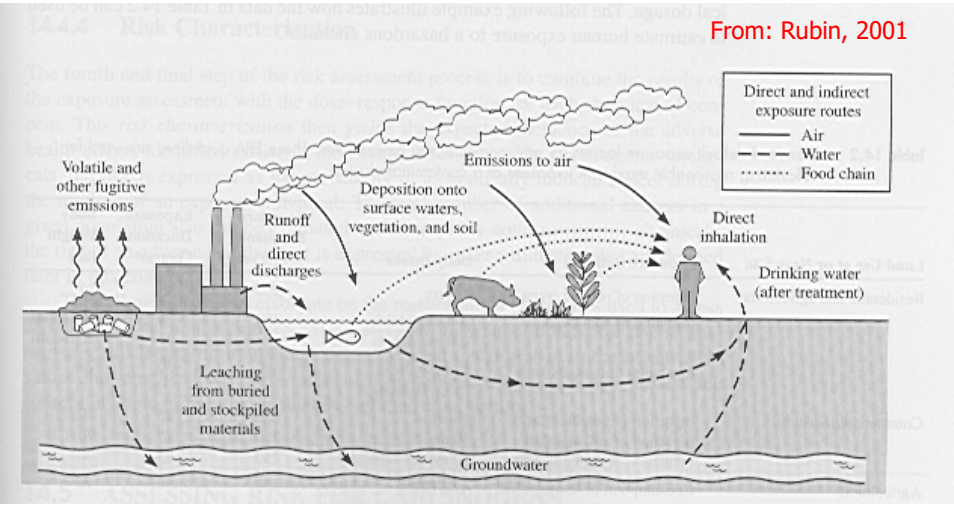
- The determination of whether a particular chemical or agent is or is not causally linked to a particular health effect.
- IARC Overall Evaluation of Carcinogenicity to Humans

1	Carcinogenic to Humans
2A	Probably Carcinogenic
2B	Possibly Carcinogenic
3	Not Classifiable
4	Probably Not Carcinogenic

Weight of Evidence

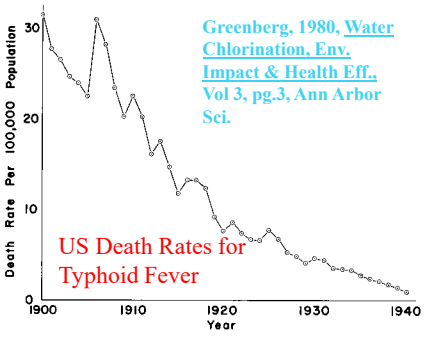
Routes of exposure

From: Rubin, 2001



Chlorination

- 1-2 punch of filtration &



Greenberg, 1980, Water Chlorination, Env. Impact & Health Eff., Vol 3, pg.3, Ann Arbor Sci.

US Death Rates for Typhoid Fever

Melosi, 2000, The Sanitary City, John Hopkins Press

Johannes J. Rook

1921-2010

- Short Biography
  - Education
    - PhD in Biochemistry: 1949
  - Work experience
    - Technological Univ., Delft (~'49-'54)
      - Laboratory for Microbiology
    - Lundbeck Pharmaceuticals in Copenhagen, (~'55-?)
    - Noury Citric acid Factory (in Holland)
    - Amstel Brewery
    - Rotterdam Water Works by 1963, chief chemist (1964-1984).
    - 1984-1986; Visiting Researcher at Lyonnaise des Eaux, Le Pecq.
- Early Research
  - 1955, Microbiological Deterioration of Vulcanized Rubber
    - Applied Micro.
  - 1964, secured funds for a GC at Rotterdam
    - Carlo Erba with gas sample loop

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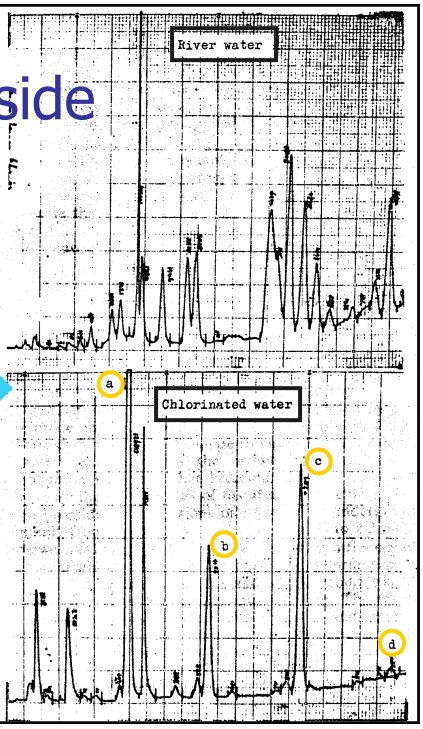
Chlorination: down side

- Johannes Rook
  - Brewery chemist
  - Started with Rotterdam WW in 1963
  - Found THMs in finished water
  - Deduced that they were formed as byproducts of chlorination
- Others
  - Uden, Christman
    - HAAs: 1980



Rook, 1974, Water Treat. & Exam., 23:234

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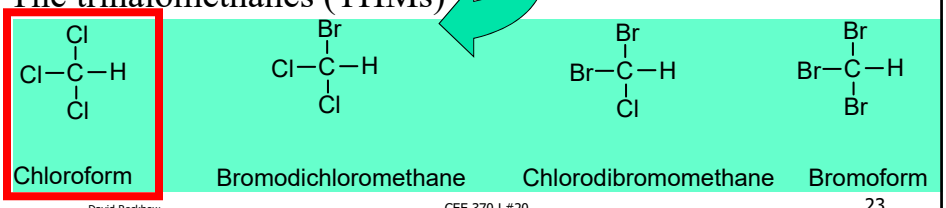
Disinfection with Chlorine

From vegetation in watershed

Cl_2 + natural organics (NOM)

The trihalomethanes (THMs)



Exposure to Chloroform

- **Deterministic upper-bounding estimates of daily intake for the general population**
  - [a] Further details on the basis for estimated figures are given in Environment Canada & Health Canada (2001).
  - [b] Inhalation and dermal intake from daily showering.

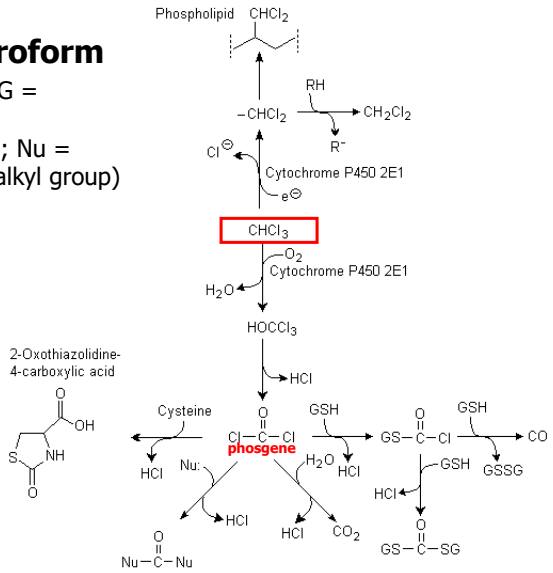
But this is simple exposure, not considering metabolism

Exposure medium	Upper-bounding estimates of intake (µg/kg body weight per day) for age groups in the general population					
	0-6 months	7 months - 4 years	5-11 years	12-19 years	20-59 years	60+ years
Outdoor air	0.21	0.45	0.35	0.20	0.17	0.15
Indoor air	16.81	36.02	28.08	15.97	13.72	11.92
Food	- (included in water data)	2.87	2.36	1.58	1.25	0.89
Drinking-water	130.6	55.28	43.43	24.73	25.90	27.20
Subtotal	147.6	94.62	74.22	42.48	41.04	40.16
Showering[b]	-	-	-	55.64	46.61	45.90

Chloroform

- **Metabolism of chloroform**
  - (GSH = glutathione; GSSG = bis(gamma-glutamyl-L-cysteinylglycine) disulfide; Nu = tissue nucleophiles; R = alkyl group)

Cytochrome P450 is a large family of enzymes (>10,000 known) that are found in plants and animals. They catalyze the oxidation of organic compound including may environmental pollutants



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Animal tests to Humans

- RfD is the reference dose.
  - RfD=LED10/UF
    - LED10 is the 95% confidence lower bound on the dose associated with a 10% extra risk
      - Equals 1.2 mg/kg/d in this case: from liver toxicity in animal studies
    - UF is the uncertainty factor
      - Equals 100 in this case: 10 for interspecies extrapolation times 10 for protection of sensitive individuals

LED=lowest effective dose

$$RfD = \frac{\text{LED10}}{\text{UF}} = \frac{1.2 \frac{mg-total-\text{exposure}}{kg-bodywt \bullet d}}{100} \approx 0.01 \frac{mg-total-\text{exposure}}{kg-bodywt \bullet d}$$

Davi

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Setting a standard

- Maximum contaminant level goal (MCLG)

$$MCLG = \frac{RfD \text{ x body weight x RSC}}{\text{daily water consumption}}$$

  - RSC is relative source contribution
- For chloroform in drinking water **70kg ~ 155 lb**

$$MCLG_{water} = \frac{0.01 \frac{mg-total-\text{exposure}}{kg-bodywt/day} 70 \frac{kg-bodywt}{person} 0.2 \frac{water-\text{exposure}}{total-\text{exposure}}}{2 \frac{L}{person/day}}$$

$$= 0.07 \, {}^{mg}/_{L}$$

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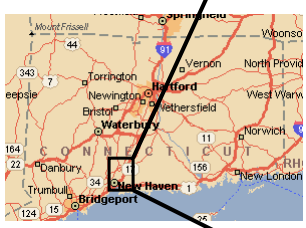
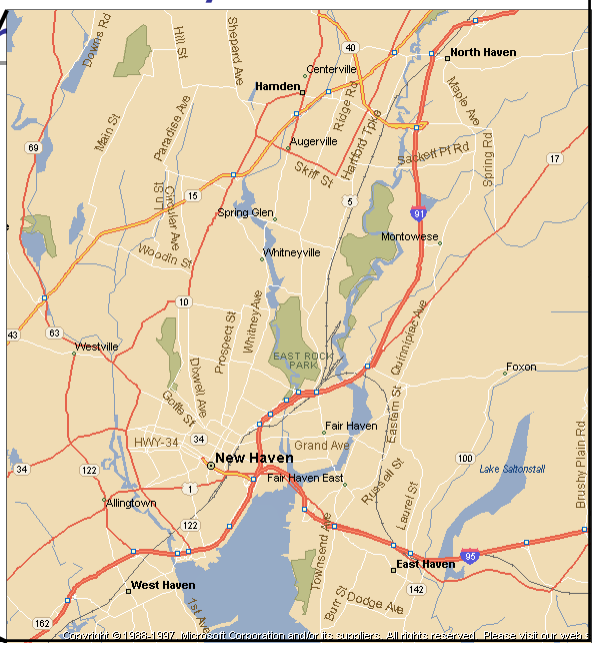
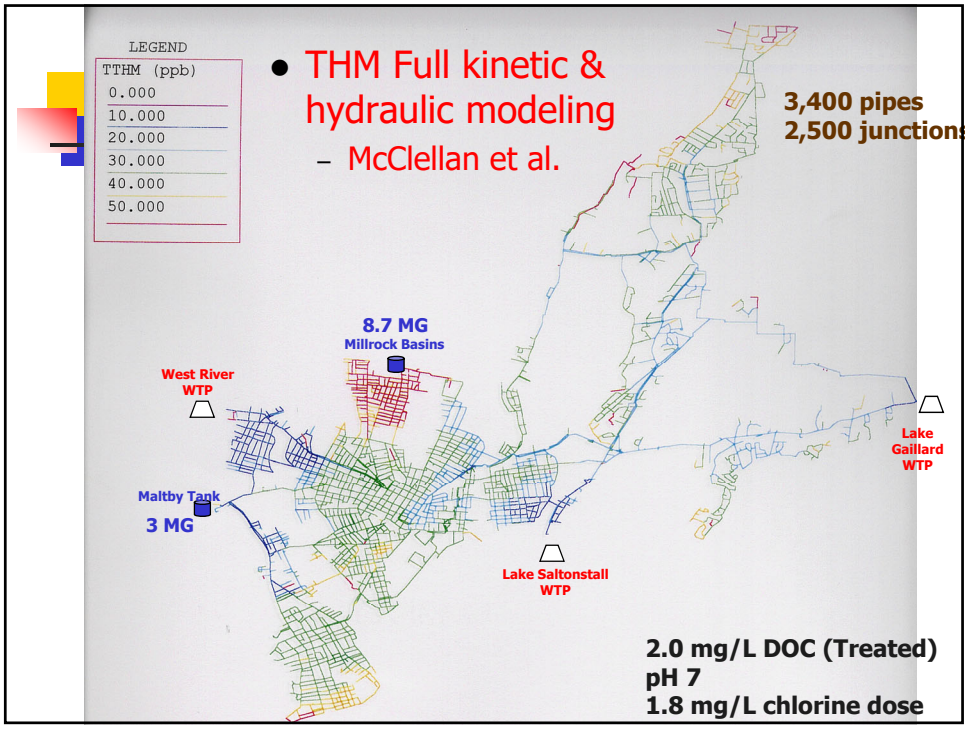
Distribution: Variability within a single system

- Example: New Haven Service Area
  - DS model







Protecting public from THMs

- Regulations
  - MCL = 80 ppb
- Where and when to measure it?
  - THM analysis is ~$100 each
  - If you measure it every 6 hrs at your house it would cost $150,000 per year
    - Do you measure at every house?
- How to tell if you're in compliance?
  - City average or every location?
  - RAA or LRAA

Environmental Justice

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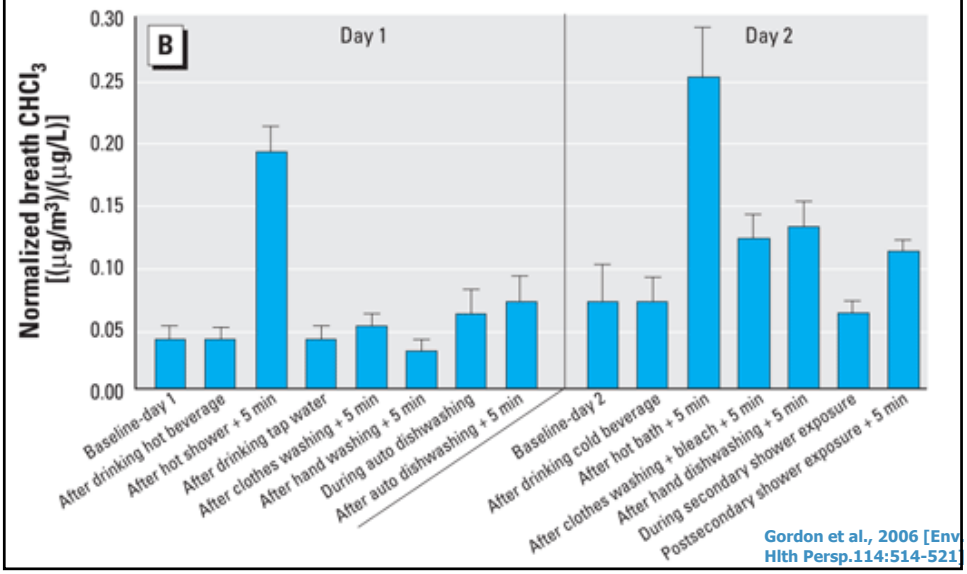
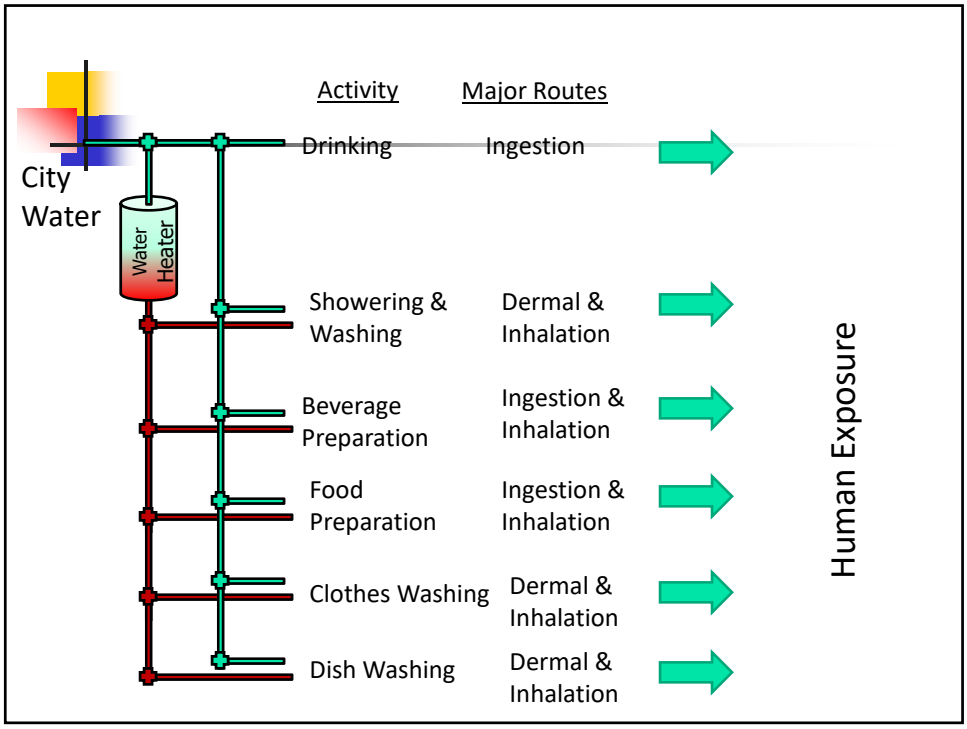
Multiple Routes of Exposure

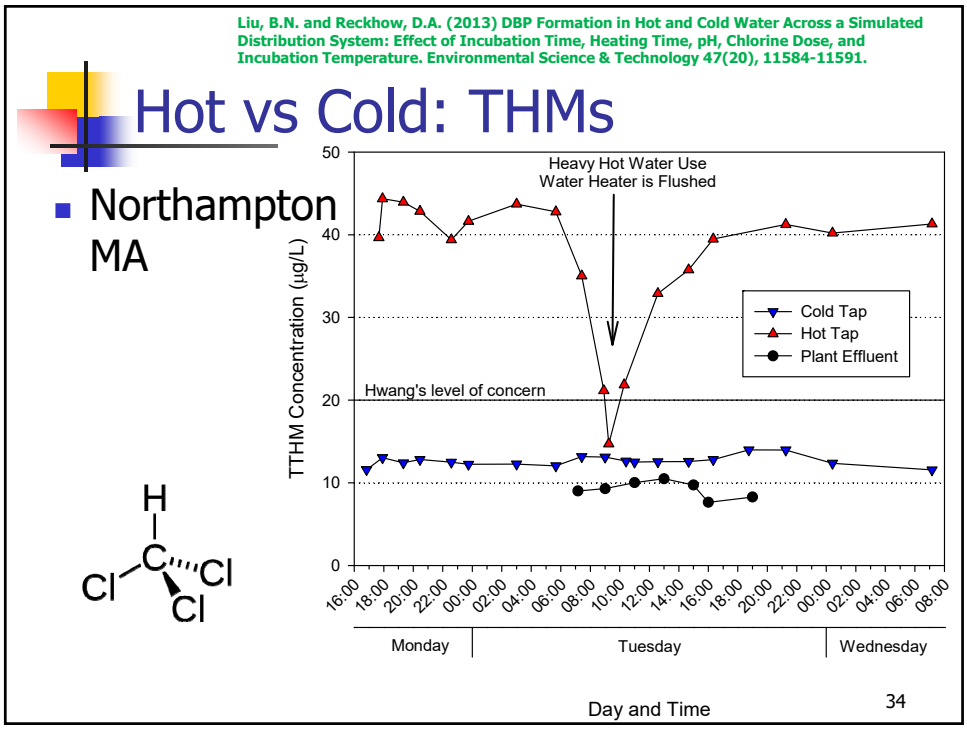


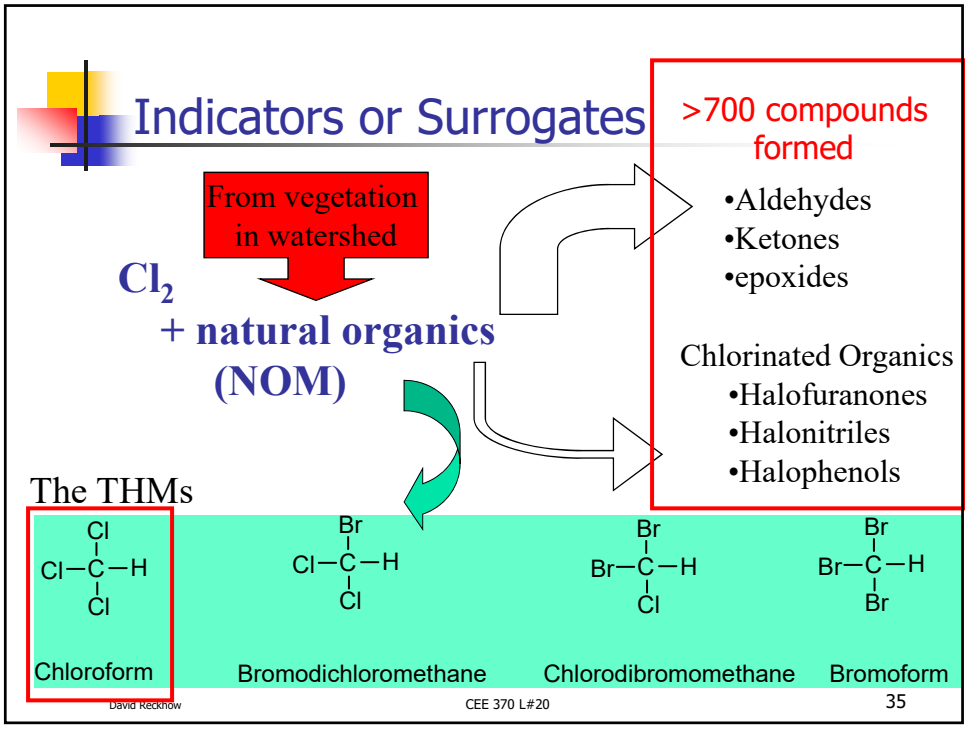
Gordon et al., 2006 [Env Hlth Persp.114:514-521]

System spatial variability Key Questions

- Is it better to live in a house that is closer to a water treatment plant?
- How do you get your dose of disinfection byproducts?
- Does one type of water heater produce better water than another?
- Could washing dishes be hazardous to your health?


Activity
Major Routes
Drinking
Ingestion
City Water
Water Heater
Showering & Washing
Dermal & Inhalation
Beverage Preparation
Ingestion & Inhalation
Food Preparation
Ingestion & Inhalation
Clothes Washing
Dermal & Inhalation
Dish Washing
Dermal & Inhalation
Human Exposure


Liu, B.N. and Reckhow, D.A. (2013) DBP Formation in Hot and Cold Water Across a Simulated Distribution System: Effect of Incubation Time, Heating Time, pH, Chlorine Dose, and Incubation Temperature. Environmental Science & Technology 47(20), 11584-11591.
Hot vs Cold: THMs
Northampton MA
Heavy Hot Water Use
Water Heater is Flushed
Cold Tap
Hot Tap
Plant Effluent
Hwang's level of concern
TTHM Concentration (µg/L)
Monday
Tuesday
Wednesday
Day and Time
34



Indicator Organisms

- Pathogens are often too difficult to monitor directly
- Indicator organisms are a type of surrogate that can be easily measured
- Ideal traits for an indicator
  - Originate only indigestive tract of humans and other warm blooded animals
  - Easily and rapidly enumerated
  - Survive outside of intestine for as long or longer than pathogens
  - Occur in high numbers
  - They are not pathogenic

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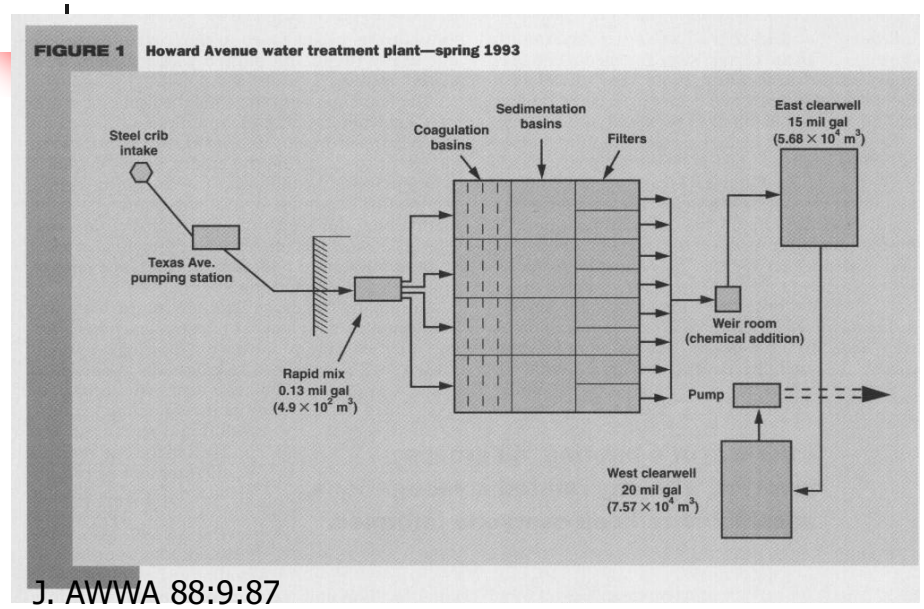
Indicators

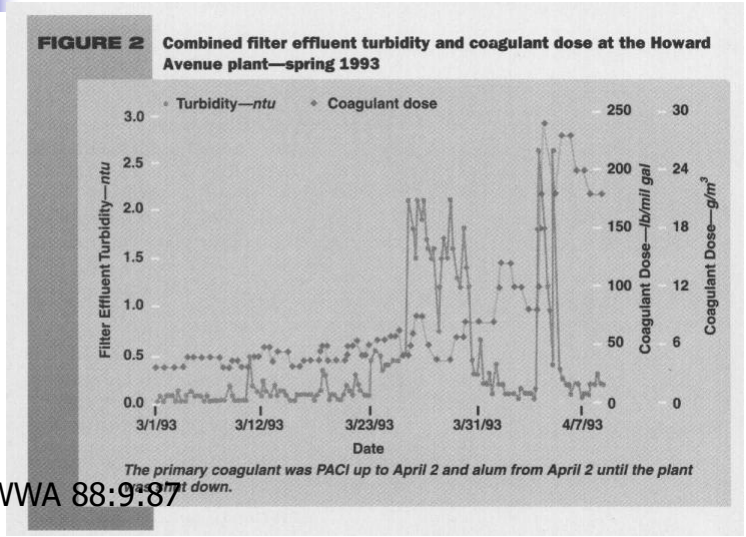
- Coliforms
  - Total Coliforms
    - Some may not be of fecal origin
  - Fecal Coliforms
    - May give false-positive results
  - *Escherichia coli*
    - Only of fecal origin

Milwaukee's Linwood Plant

- March & April 1993
  - Cryptosporidium outbreak
    - ~400,000 ill

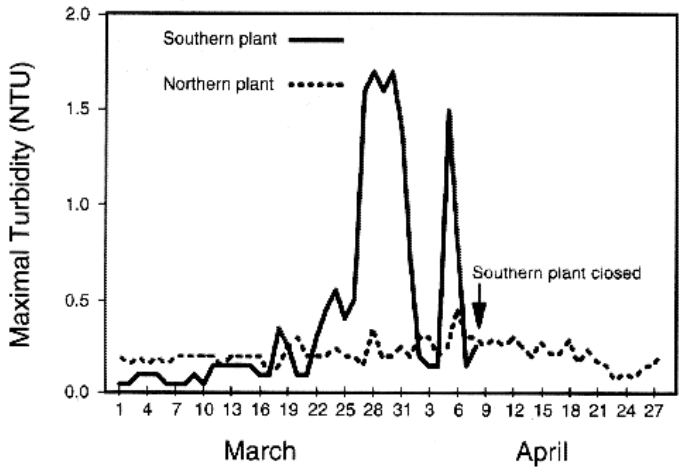


J. AWWA 88:9:87



J. AWWA 88:9:87

Two plants supply water



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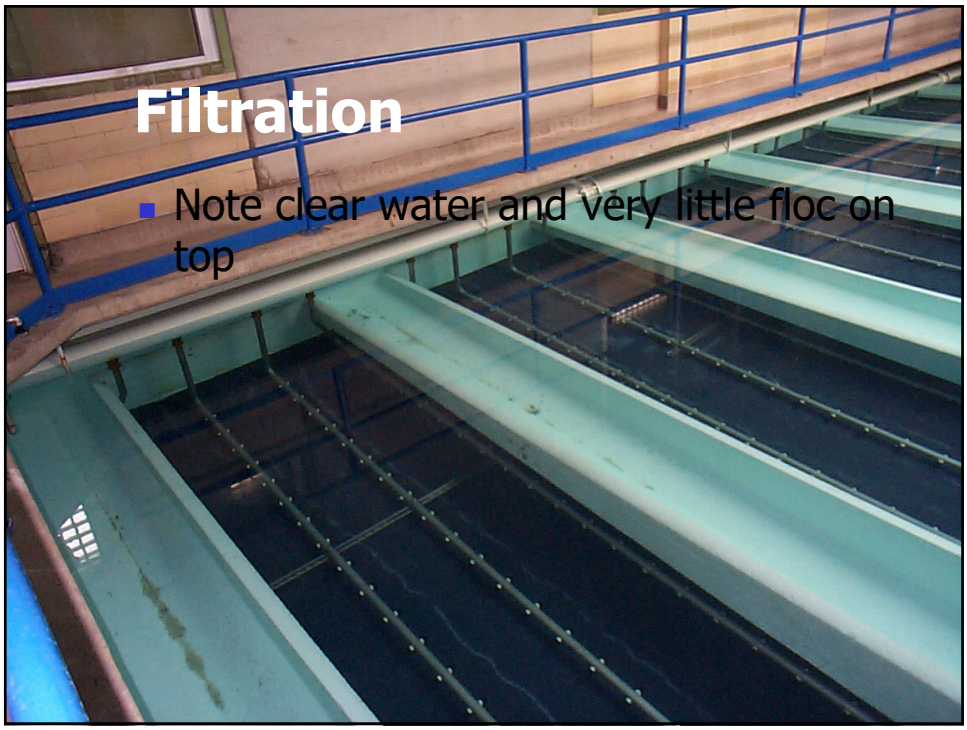
Filtration

- Note clear water and very little floc on top



NEJM, Volume 331:161-167, July 21,1994

Milwaukee Outbreak I

- Milwaukee Water Works (MWW)
  - Obtained water from Lake Michigan
  - Examination of Untreated and Treated Water
    - Revealed an increase in the turbidity of treated water beginning on March 21
      - Unprecedented levels of turbidity from 3/23/-4/5
- April 7th advisory to all MWW customers to boil water.
  - Howard Ave WT Plant closed on 4/9

NEJM, Volume 331:161-167, July 21,1994

Milwaukee Outbreak II

- 14 Clinical Laboratories
  - Surveillance
    - Retrospectively (3/1-4/6)
    - Prospectively (4/7-4/16)
- Before April 7th 12 of 14 laboratories tested for Crypto, only at the request of a physician
- 739 lab confirmed cases from 3/1-5/30
  - 567 had telephone numbers
  - 312 interviewed
  - 285 (91%) onset 3/1-5/15

NEJM, Volume 331:161-167, July 21,1994

Milwaukee Outbreak III

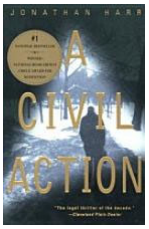
- Laboratory Surveillance
  - 3/1-4/6
    - 12 of 42 (29%) specimens positive for *Cryptosporidium*
  - 4/8-4/16
    - 331 of 1009 (33%)specimens positive for *Cryptosporidium*

NEJM, Volume 331:161-167, July 21,1994

Milwaukee Outbreak IV

- Lab confirmed cases
  - 285 confirmed cases
    - 170 (60%) female
    - 130 (46%) hospitalized
    - 48 (17%) immunocompromised
    - Mean age 41 years (2 months- 93 years)
    - All had diarrhea
      - 265 (93%) watery
    - Median duration of diarrhea 9 days (1-55)
    - Onset of illness 3/1-5/15

Jan Schlichtmann



"A Civil Action"

WELLS G AND H
WOBURN, MIDDLESEX COUNTY, MASSACHUSETTS
Comprehensive Environmental Response, Compensation and Liability Information System (**CERCLIS**) No. MAD980732168

David Reckhow CEE 370 L#20 48

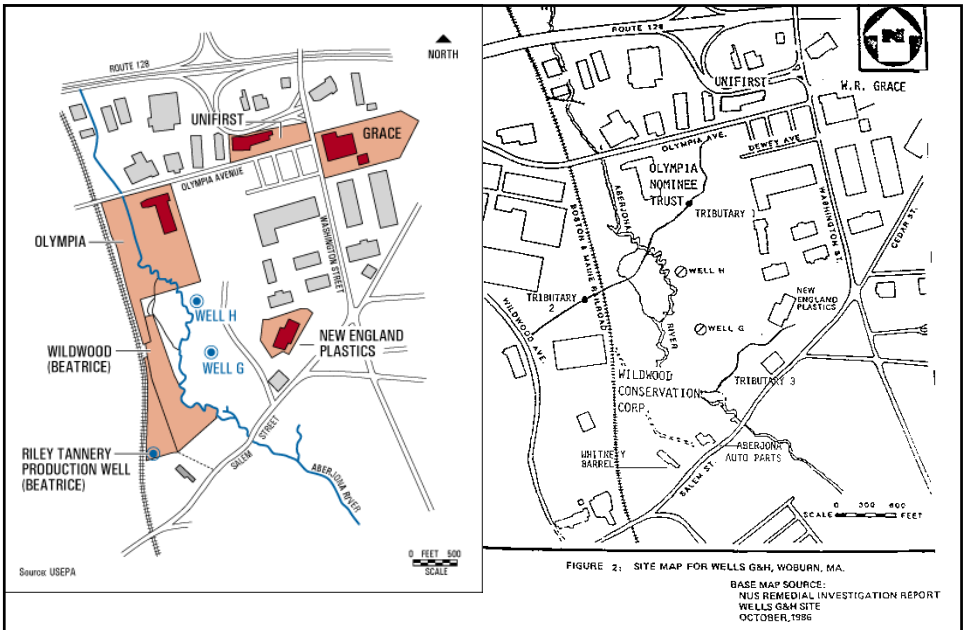


FIGURE 2: SITE MAP FOR WELLS G&H, WOBURN, MA.

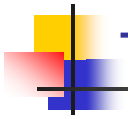
BASE MAP SOURCE:
NUS REMEDIAL INVESTIGATION REPORT
WELLS G&H SITE
OCTOBER, 1986

Summary

- MDPH - the city's rate of childhood **leukemia** was four times higher than would be statistically expected in a community of its size.
- 1980 - the Harvard School of Public Health **correlated** leukemia cases with the distribution pattern of water from wells G and H to show that leukemia was most highly concentrated in neighborhoods that had received most of their water from the wells.
- 1982, a legal **complaint** was filed by eight families in east Woburn, Massachusetts, against three local industries for the improper handling and disposal of toxic chemicals. The complaint alleges that the toxic chemicals entered the groundwater flow system and were pumped by municipal wells G and H into the water supply of a local neighborhood, and that the consumption of the contaminated water caused leukemia, liver disease, central nervous system disorders, and other unknown illness and disease.

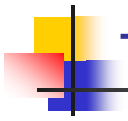
Summary

- In December 1982., U.S. EPA proposed that the 330-acre area around municipal wells G and H be added to the **NPL**.
- Another NPL site, the Industri-Plex Site, is in Woburn less than one mile upstream of municipal wells G and H.



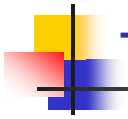
Time Line

- 1648-Woburn's first tannery commences operations.
- 1865-The city's leather tanning industry hits its stride, with 21 tanning and currying shops in action.
- 1863-1929 Woburn Chemical Works builds one of America's largest industrial complexes: 90 buildings spread over 417 acres on what is now generally the Industriplex waste site, which is upriver from Wells G & H.
- 1910- John J. Riley Tannery is established near the Aberjona River.
- 1927 Woburn constructs sewer because of continuing pollution of Aberjona River and Upper Mystic Lake.
- 1958 The City of Woburn's water consultant (Whitman and Howard) warns that the Aberjona River Valley groundwaters are polluted and should not be used for a public water supply.



Time Line

- 1960 W. R. Grace & Co. opens a small machine shop on Washington Street.
- 1964 The City of Woburn installs Well G in the Aberiona River Valley.
- 1967 The City installs Well H in the Valley.
- 1975 The Massachusetts Department of Health indicates that Wells G & H are contaminated.
- 1979 The Massachusetts Department of Environmental Quality Engineering finds that Wells G & H are contaminated with several volatile organic compounds (VOCs), and the wells are closed.

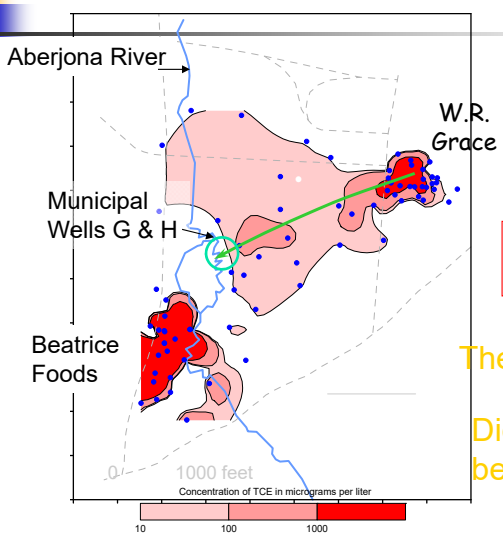


Time Line

- 1982 - Eight Woburn families sue Grace and Beatrice Corp., alleging that eight persons (seven children and an adult) had contracted leukemia from exposure to Wells G & H water allegedly contaminated by the two companies. (A third company, UniFirst Corp., was later added to the suit but quickly settled with the plaintiffs.)
- 1986 - After an 80-day trial, finding dismissed by the judge who orders a new trial. Shortly thereafter, Grace and the families settle.
- Between 1964 and 1979, Wells G & H supplied 25% of the drinking water for Woburn. In 1979, the State found four Chlorinated Solvents in the wells with concentrations over 500 ppb.

Woburn Site

TCE in 1985



Geology:
buried river valley of glacial outwash and ice contact deposits overlying fractured bedrock

Wells G&H operated from October 1964- May 1979

The trial took place in 1986.

Did TCE reach the wells before May 1979?

UniFirst Corportation

- Formerly a dry cleaning facility - Interstate Uniform Service Corporation (IUSC) (1966-1983).
- From 1977-1982, a 5,000-gallon above-ground tank was used to store the dry-cleaning agent tetrachloroethylene.
- In 1988 Ebasco Services Inc. reported the recovery of less than two liters of DNAPL from a monitoring well installed near the location of the removed storage tank. The liquid contained 19,000,000 ug/l of tetrachloroethylene.

Cryovac Division of W.R. Grace and Co.

- A food wrapping manufacturer since 1961. W.R. Grace and Co. utilized degreasing agents such as trichloroethylene at its facility. W.R. Grace and Co. made use of a pit behind the plant for waste disposal, and discharged waste into the city's sewer system. In accordance with an EPA Administrative Order, the pit was excavated and six 55-gallon drums of liquid waste and contaminated soil were removed to a Resource Conservation and Recovery Act of 1976 (RCRA)-approved disposal facility in June, 1983.

New England Plastics Corporation

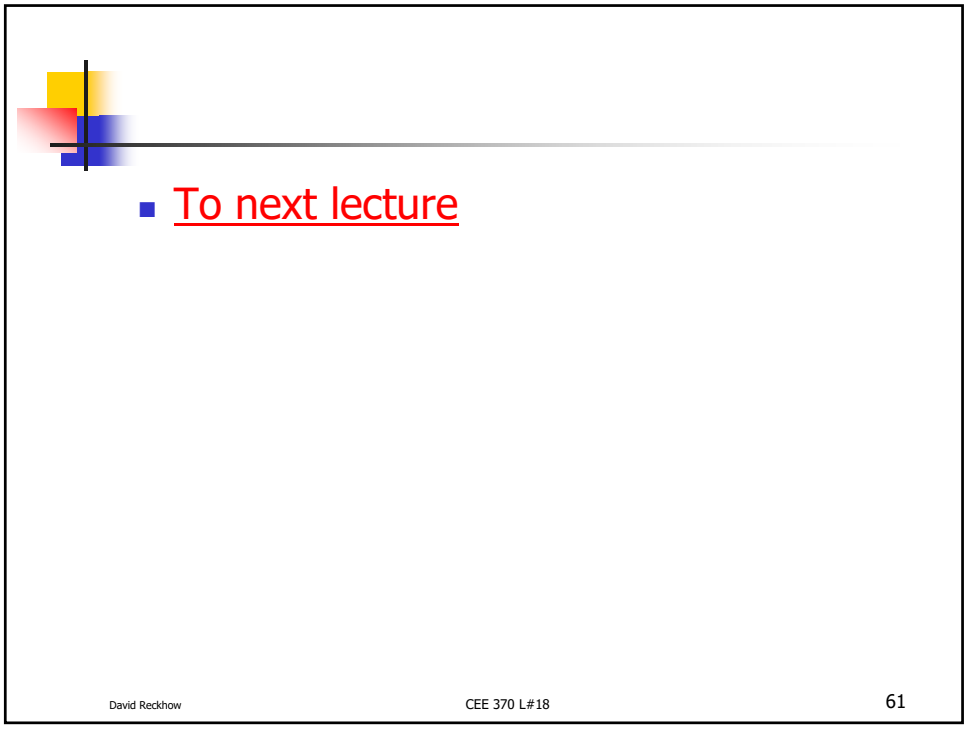
- A manufacturer of solid vinyl siding and various other plastic products.
- Prospect Tool and Die Company is also located within the same building.
- In December 1986, water from an industrial well which tapped the bedrock aquifer was found to be contaminated with various volatile organic compounds (PCE & TCE).
- In 1988, effluent from the New England Plastics Corporation was found to enter the Aberjona River via a drainage ditch.

Olympia Nominee Trust Corp.

- 1970 – 200 to 500 five-gallon containers of arsenic trioxide were discovered on the property.
- The Hemingway Transport Co., which owned the property since 1980, had four underground storage tanks at the trucking terminal facility.
- In May 1983, a 6,280-gallon gasoline tank was found to be leaking, and was removed in July 1983. It is unknown when the tanks were installed and when the gasoline tank began leaking.

Wildwood Conservation Corporation

- John J. Riley sold the land to Beatrice Foods, Inc., in 1978, then repurchased the property in 1983.
- Established the property as the Wildwood Conservation Corporation in 1985. Various trails leading from two neighboring facilities, Whitney Barrel Company and Murphy Waste Oil Company, to the property existed during the period 1966-1983.
- On the property, extensive contamination consisting of sludge, discolored soils, trash, 55-gallon drums, paint cans and debris piles has been documented. John J. Riley Tannery has an industrial water supply well on the property.


To next lecture
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