Updated: 5 September 2019

Print version

CEE 370 Environmental Engineering Principles

Lecture #2
Introduction II:
Legislation & Regulations

Reading: M&Z: Chapter 1; Loehr paper (handout)

Hardin's "Tragedy of the Commons" Science, 13 Dec 1968 Also in html

(pg 1243)

Course Administration

- Schedule
  - Lecture MWF: 10:10 – 11:00
  - Labs MTuWTh: 2:30-5:30
- Course Syllabus
- Book: Mihelcec & Zimmerman, 2014
  - supplemented by other texts

e.g., Davis & Masten, 2009

- Detailed Course Outline
- Homework policy
  - No more than 9; most graded
- Exams
  - Mid-Term: Wed Oct 23rd at 7:30PM
  - Final: Thursday Dec 19th at 8:00AM
- Web site
  - http://www.ecs.umass.edu/cee/reckhow/courses/370/

Textbook

- Mihelcic & Zimmerman, 2014
  - An excellent overview
  - Presents introduction to field and scientific foundations
    - Good prelude to CEE 471, which is more focused on water engineering
  - Good coverage of sustainability, LCA
  - However, no book is error-free
    - Please report other errors you might find
    - I'll pass on anything I notice to you

Other reference texts

- Mihelcic, James R., Fundamentals of Environmental Engineering. J. Wiley & Sons Inc., 1999
  - One copy in the UMass Science & Engineering Library
- Nazaroff & Alvarez-Cohen, Environmental Engineering Science, John Wiley & Sons, Publ., 2001
  - One copy in the UMass Science & Engineering Library
- Masters, Introduction to Environmental Engineering and Science, Prentice Hall, 2nd Edition, 1998.
  - Two copies in the UMass Science & Engineering Library: TD145 .M33 1998
- Sincero & Sincero, Environmental Engineering: A Design Approach, Prentice Hall, 1996.
- Henry & Heinke, Environmental Science and Engineering, 2nd Edition, Prentice Hall, 1996.
- Davis & Cornwell, Introduction to Environmental Engineering, 4th Edition, McGraw-Hill, Inc., 2008
- Vesilind & Morgan, Introduction of Environmental Engineering, Thomson, 2004
  - One copy in the UMass Science & Engineering Library
- Rubin, Introduction to Engineering & the Environment, McGraw-Hill, 2001
  - One copy in the UMass Science & Engineering Library

Homeworks

- Best way to learn quantitative aspects of the course
- Good preparation for the exams
- Must be turned in on time
- Must be organized and legible
- Many issues regarding presentation
  - Significant figures

Quantity	Number of Significant Figures
4,784	
36	
60	
600	
6.00×10^2	
30.02	
0.02	
0.020	
600.00	

Homeworks

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Quantity	Number of Significant Figures
4,784	4
36	2
60	1 or 2
600	1 or 2 or 3
6.00×10^2	3
30.02	4
0.02	1
0.020	2
600.00	5

Oddly, no one bothered to photograph it. This widely distributed photo is actually from an earlier fire in 1952.

On June 22, 1969 the Cuyahoga River Caught fire,

and so did the US environmental movement (see: 8/1/69 issue of Time Magazine)

But the seeds were planted earlier

- Two environmental pioneers

Birth of the environmental movement

Rachel Carson

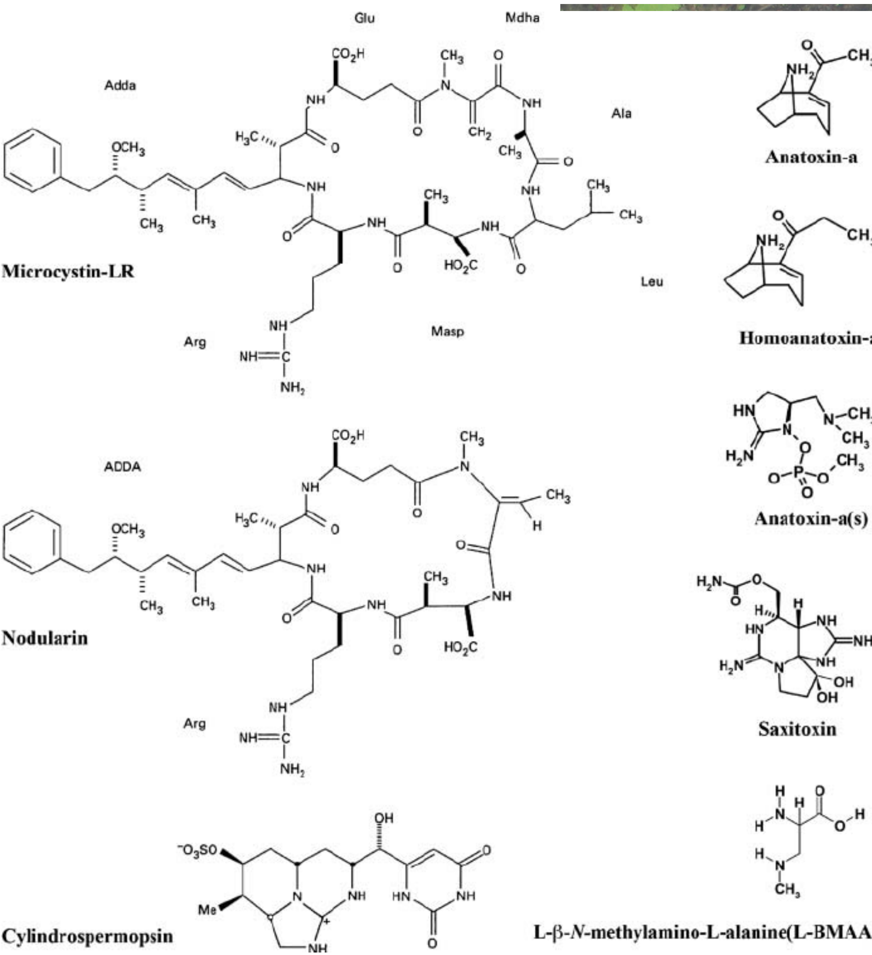
- 1907-1964

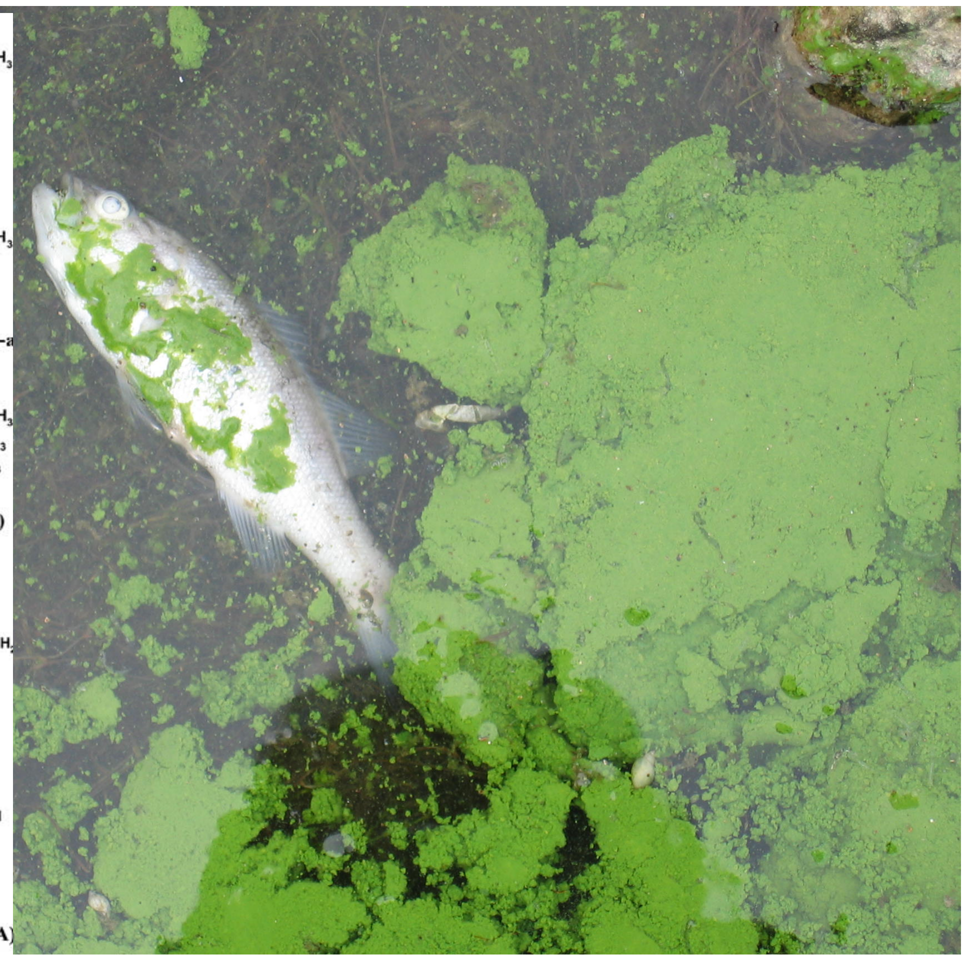
James Lovelock

- 1919-present

Cyanobacteria

- [WBZ Aug 13, 2019 news story]()






TIM
The Poisoning Of An American City
Toxic water. Sick kids.
And the incompetent
leaders who betrayed Flint
By Josh Sanburn
time.com


LEAD CONTAMINATION IN
NEWARK, NJ
DRINKING WATER


FLINT WATER PLANT

Contaminants in Flint Hot Water

- Water Defense, an environmental nonprofit
  - 2010: founded by actor **Mark Ruffalo**
  - 2013: Scott Smith appointed chief technology officer
  - The Water Bug
  - The Huffington Post, May 23, 2016
    - "*Mark Ruffalo's water nonprofit has allied itself with an opportunistic sponge salesman*"
  - Recommended that Flint residents not bathe in the city's water

The Media Circus

- Ruffalo advises against bathing
  - Cites elevated DBPs in water heaters
  - Enteric illnesses increased as a result?

May 4, 2016

May 5, 2016

May 31, 2016

Environmental Engineering

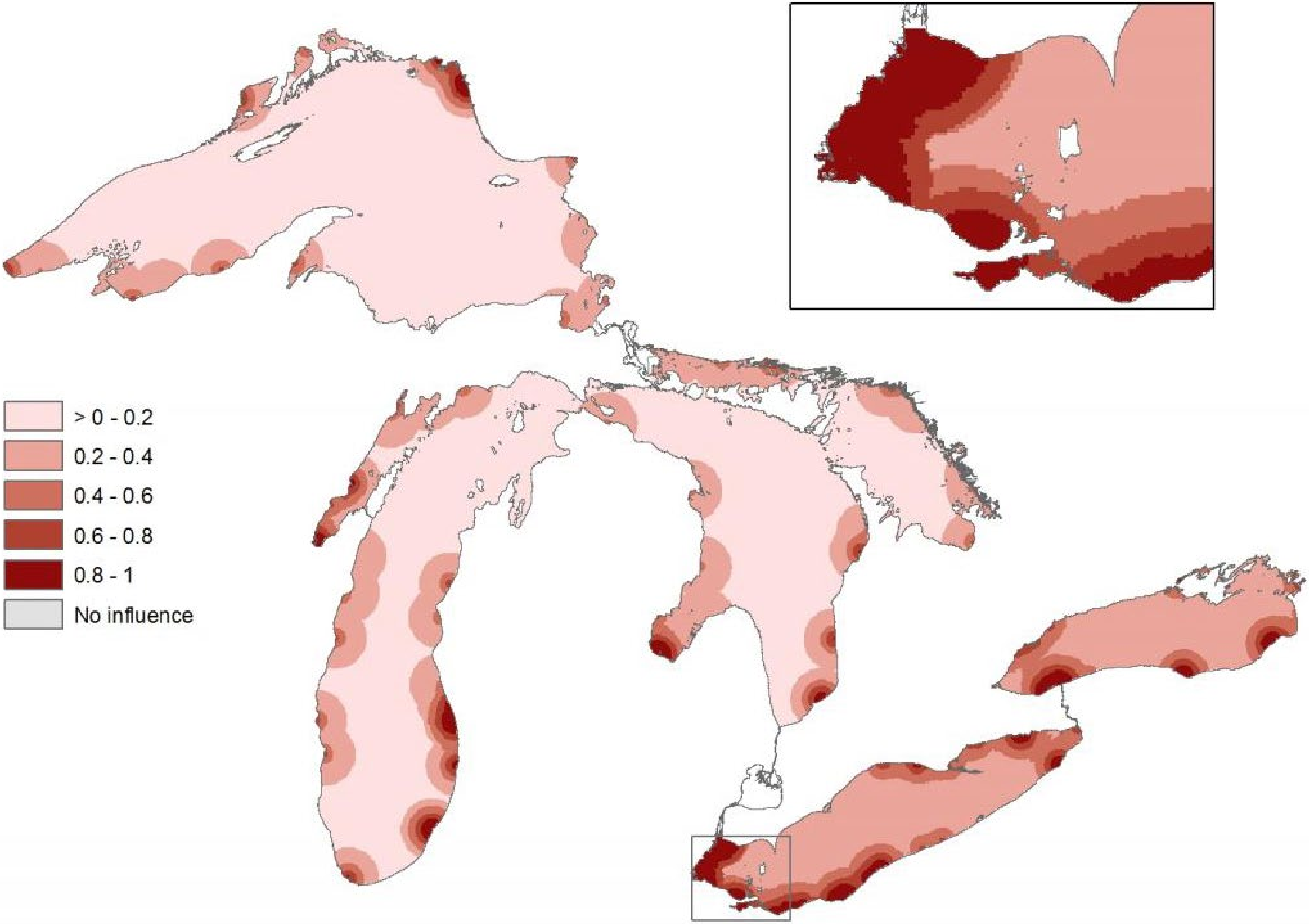
- The application of science and engineering principles to minimize the effect human activity has upon the environment.
  - We cannot possibly eliminate human effects on the environment, but such effects can be minimized through public education, conservation, regulation, and the application of good engineering practice.
    - Ray
- A field in which one applies the basic fundamentals of mathematics, physics, chemistry and biology to the protection of human health and the environment
    - Mihelcic, 1999

Sustainability

- *"Development which meets the need of the present without compromising the ability of the future to meet its needs"*
  - Brundtland Commission report, 1986

Satellite view

- Green color is ??

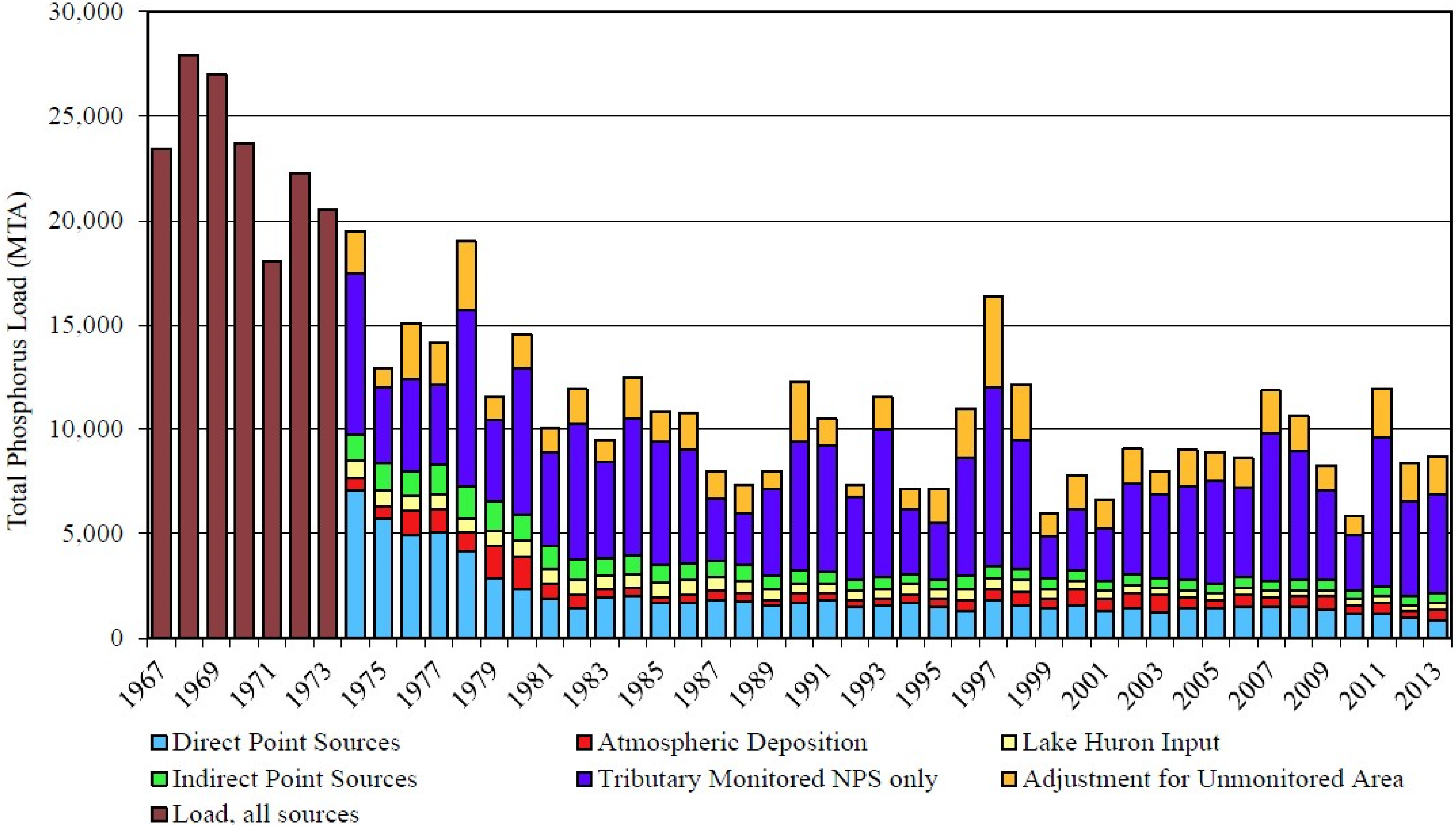


> 0 - 0.2
0.2 - 0.4
0.4 - 0.6
0.6 - 0.8
0.8 - 1
No influence

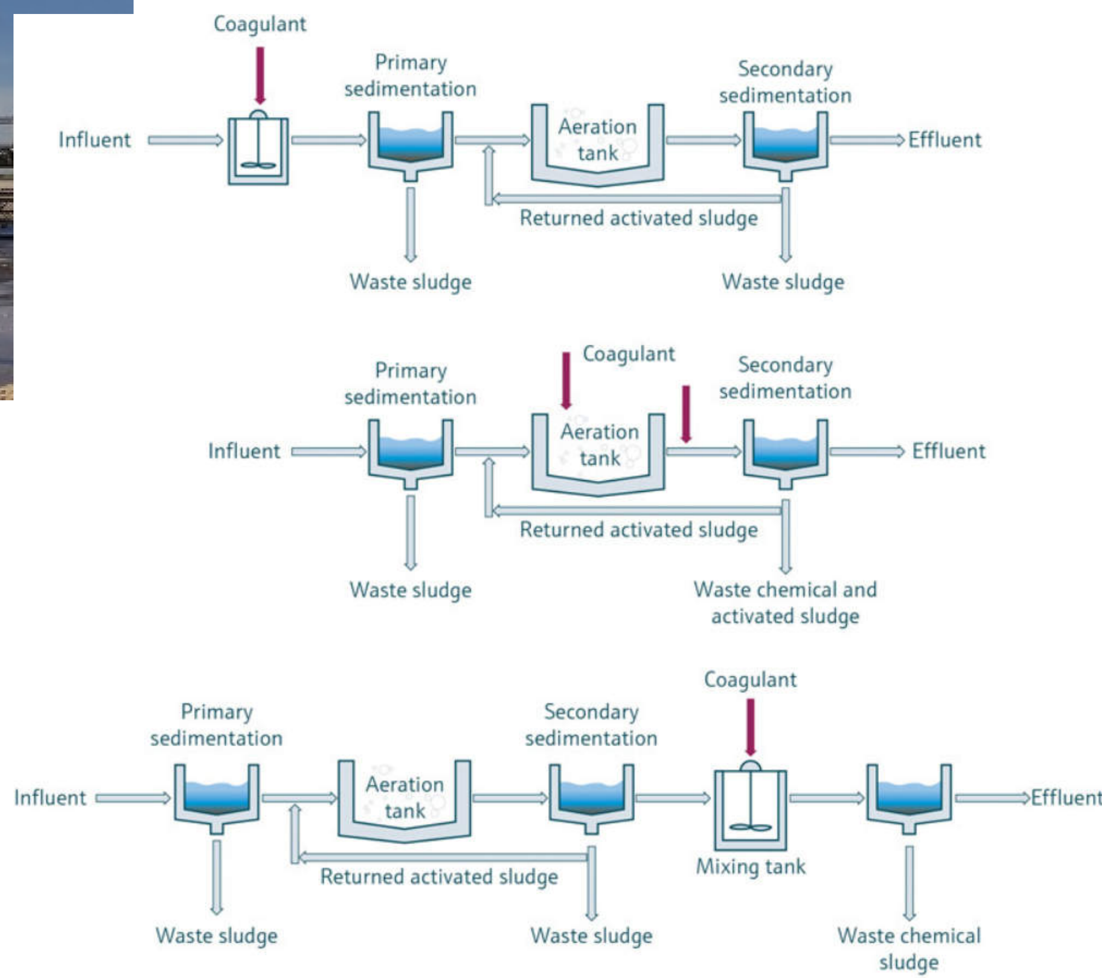
Cultural Eutrophication

- Many correlated WQ problems
  - Floating mats of algae
  - Low DO
  - High P?

Phosphorous loading to Lake Erie



Better wastewater treatment



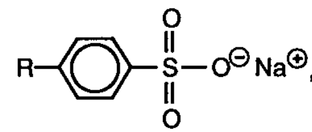
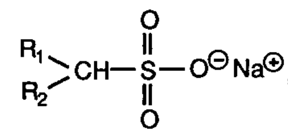
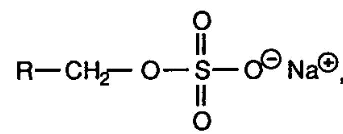
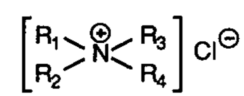
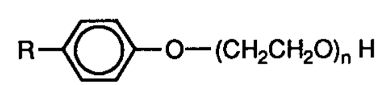

AUTOMATIC DISHWASHER DETERGENT
Cascade
Advanced Deep Cleaning Power
Electrasol
ADVANCED
All in 1
Cascade COMPLETE
Cascade COMPLETE Bleach
+25% FREE
QUANTUM
+25% FREE!
25 Gelpacs for the Price of 20!
Cascade pure ESSENTIALS
Electrasol
finish
GELPACS
20

Surfactants

- Anionics
  - 65%
- Cationics
  - 7%
- Nonionics
  - 28%

From: Schwarzenbach et al., 1993, pg. 38

TABLE 2.6 Examples of Commercially Important Surfactants[a]

Common Name of Surfactant Class (Acronym)	General Structure
	Anionic Surfactants
Soaps	$R-CH_2-COO^{\ominus}Na^{\oplus}$, $R = C_{10-16}$
Linear alkylbenzene sulfonates (LAS)	 $R = C_{10-13}$
Secondary alkyl sulfonates (SAS)	 $R_1, R_2 = C_{11-17}$
Fatty alcohol sulfates (Alkyl sulfates, FAS)	 $R = C_{11-17}$
	Cationic Surfactants
Quaternary ammonium chloride (QAC)	 $R_1 = R_2 = C_1$, $R_3 = R_4 = C_{16-18}$
	Nonionic Surfactants
Alkylphenol polyethyleneglycol ethers (APEO)	 $R = C_{8-12}$, $n = 5-10$
Fatty alcohol polyethyleneglycol ethers (AEO)	$R-CH_2-O-(CH_2CH_2O)_n H$, $R = C_{7-17}$, $n = 3-15$

[a] From Piorr (1987).

See: Knud-Hansen Paper

Powdered Detergents

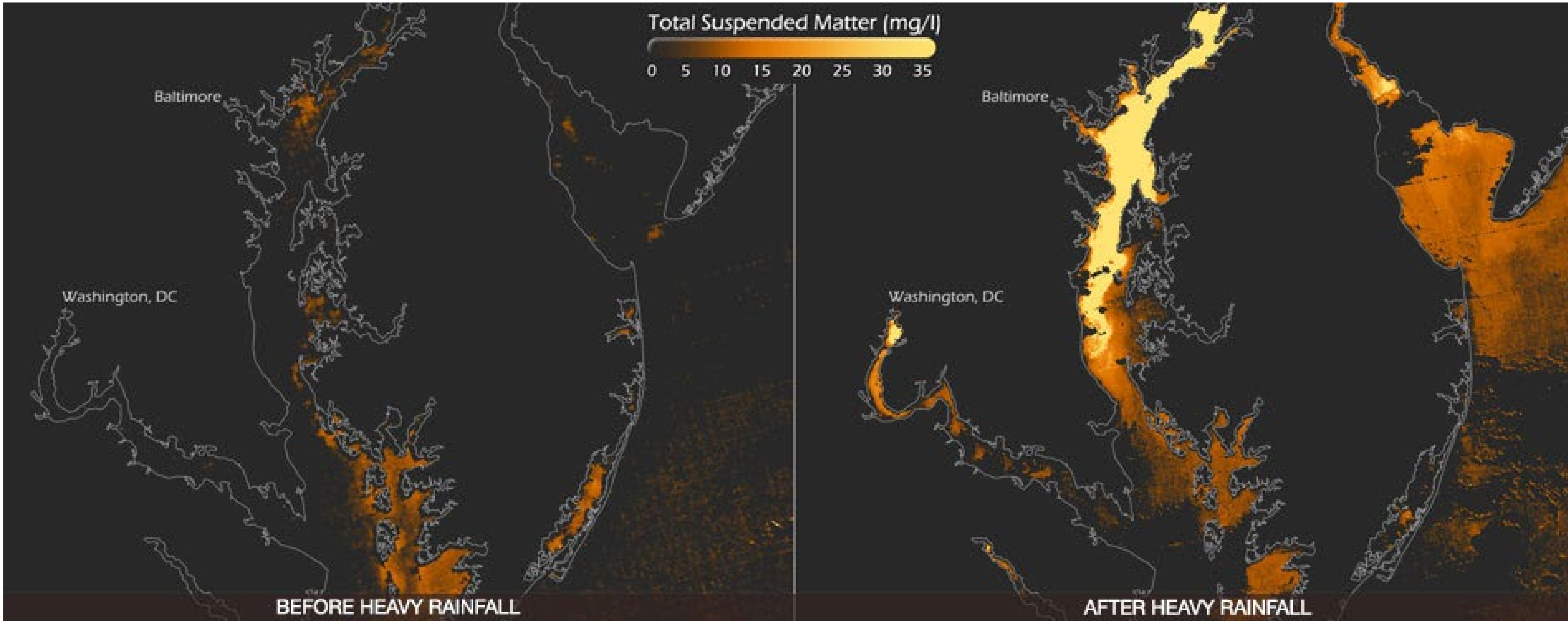
- Typical Formulation

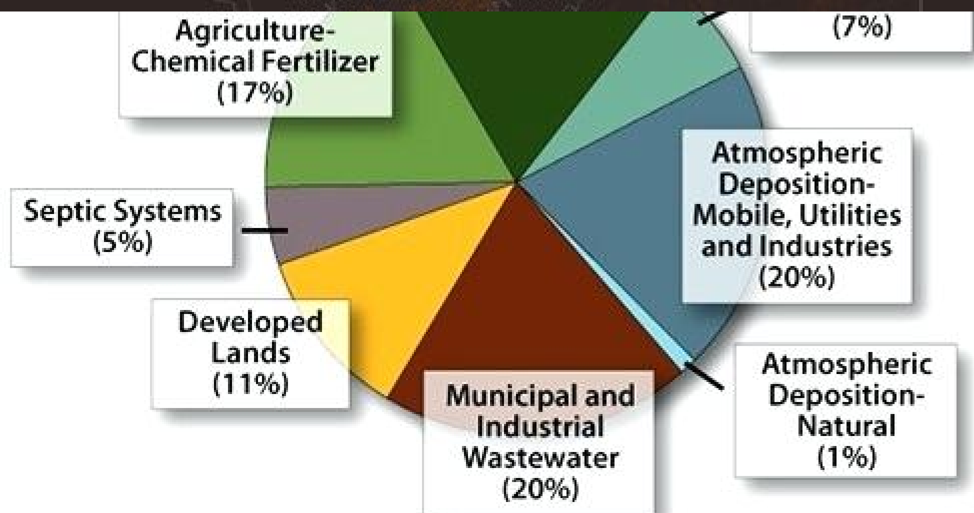
Component	Examples
Anionic surfactants	Alkylbenzene sulfonates Fatty alcohol sulfates Fatty alcohol ether sulfates Alpha-olefln sulfonates
Nonionic surfactants	Alkyl and nonylphenyl poly(ethylene glycol) ethers
Suds-controlling agents	Soaps, silicon oils, paraffins
Foam boosters	Fatty acid monoothanol amides
Chelaters (builders)	Sodium tripolyphosphate
Ion exchange	Zeolite 4A, poly(acrylic acids)
Alkalies	Sodium carbonate
Cobuilders	Sodium citrate Sodium Nitrilotriacetate
Bleaching agents	Sodium perborate
Bleach activators	Tetraacetylethylenediamine
Bleach stabilizers	Ethylenediaminetetraacetate
Fabric softeners	Quaternary ammonium compounds
Antiredeposition agents	Cellulose ethers
Enzymes	Proteases, amylases
Optical brighteners	Stilbene derivatives
Anticorrosion agents	Sodium silicate
Fragrances	
Dyes and blueing Agents	
Formulation aids	
Fillers and water	Sodium sulfate

NTA

Liquid Detergents

Component	**Examples**
Anionic surfactants	Alkylbenzene sulfonates Fatty alcohol ether sulfates Soaps
Nonionic surfactants	poly(ethylene glycol) ethers, Soaps
Suds-controlling agents	Soaps
Foam boosters	Fatty acid alkanolamides
Enzymes	Proteases
Builders	Potassium diphosphate sodium tripolyphosphate sodium citrate sodium silicate
Formulation aids	Xylene sulfonates, ethanol, propylene glycol
Optical brighteners	Stilbene derivatives
Stabilizers	Triethanolamine
Fabric softeners	Quaternary ammonium salts
Fragrances	
Dyes	
Water	





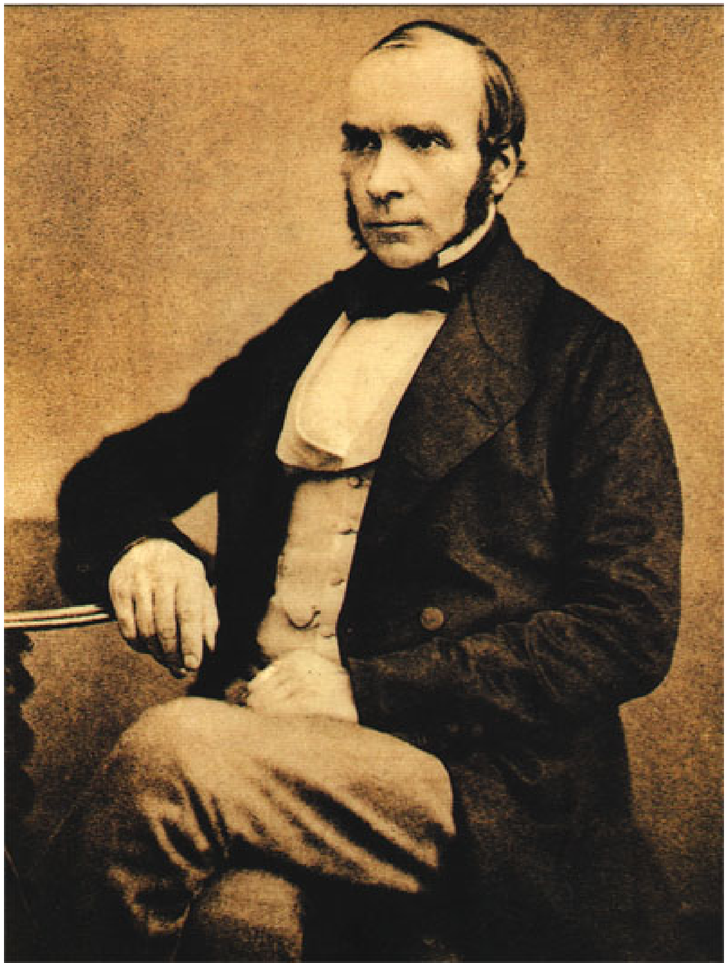
Note: Does not include loads from the ocean, tidal shoreline erosion, or direct atmospheric deposition to tidal waters. Wastewater loads based on measured discharges; other loads are based on an average-hydrology year using the Chesapeake Bay Program Watershed Model Phase 4.3 (Chesapeake Bay Program Office, 2009).

There once was a time when …

- We had no clean drinking water sources, treatment or distribution systems
- No wastewater collection, treatment and discharge systems

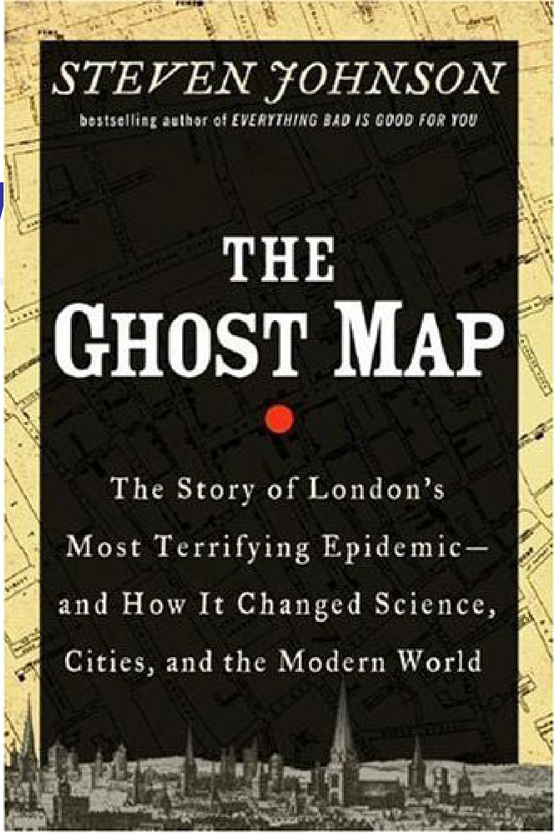
Who is this?

- What did he do for us?

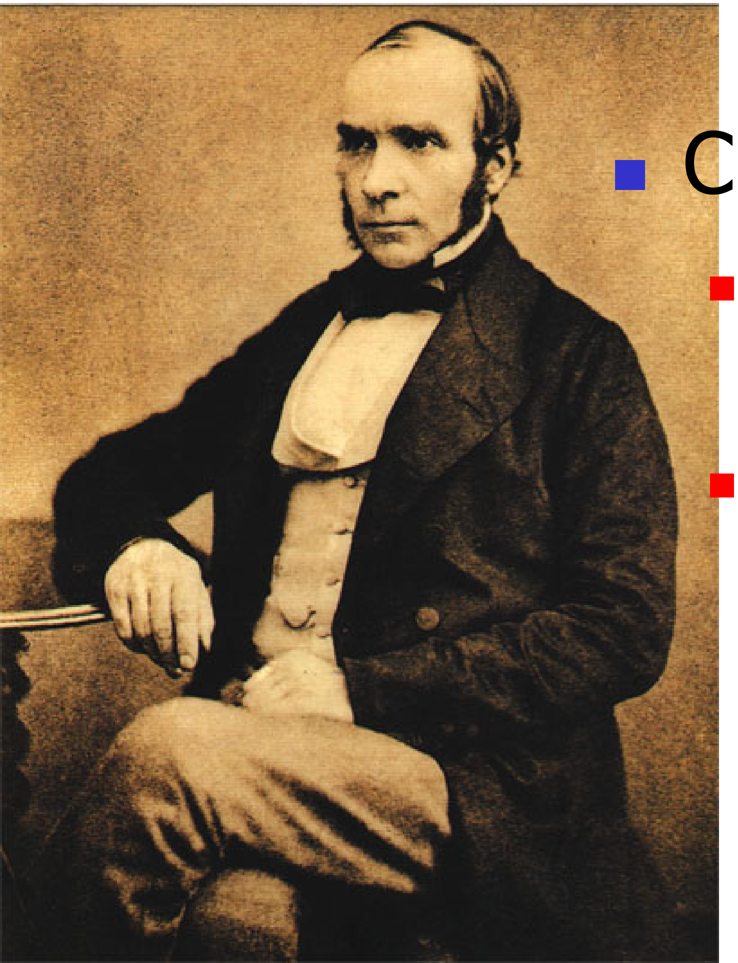


John #1: Dr. John Snow

2007

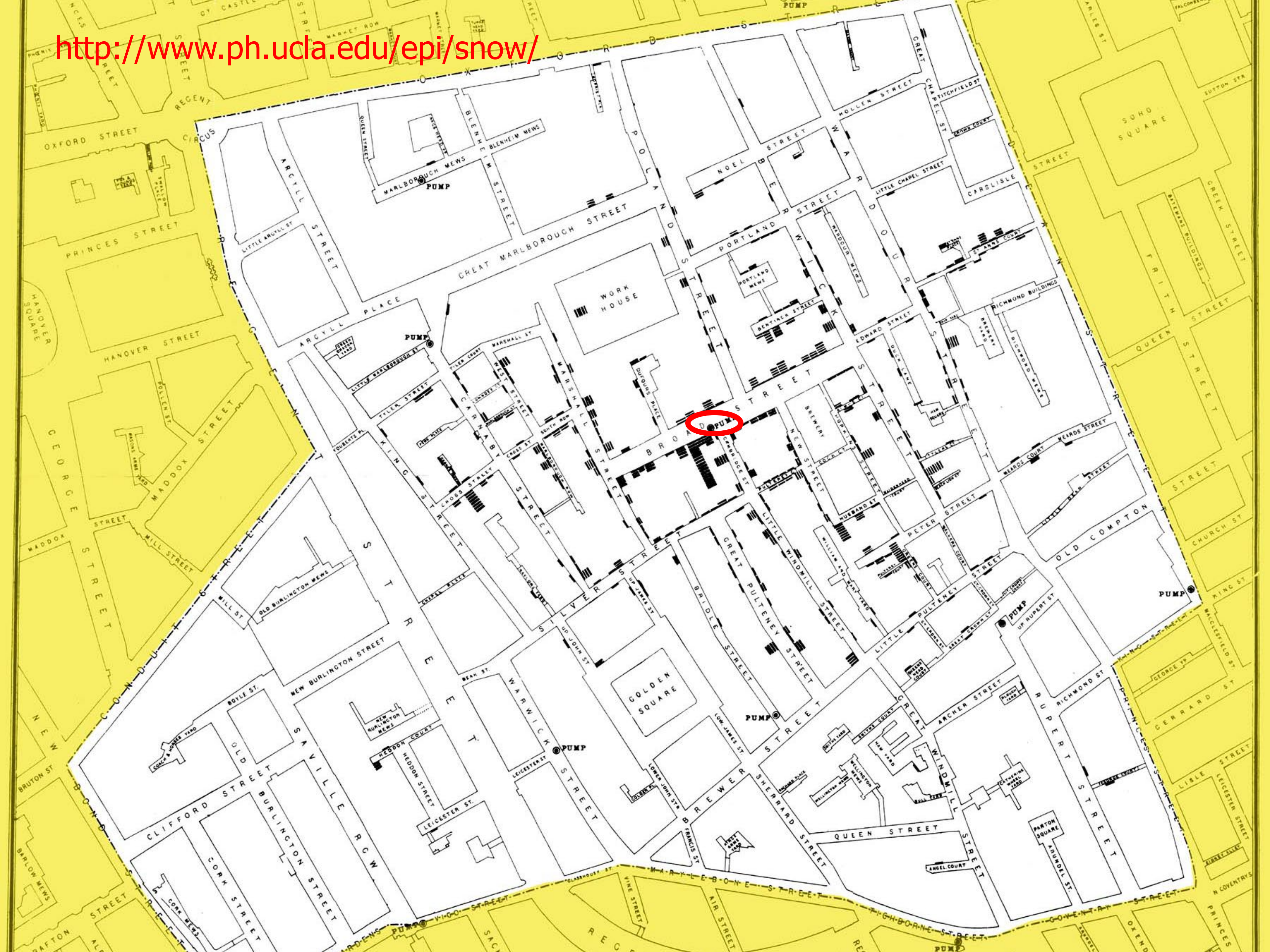


1813-1858



- Cholera
  - First emerged in early 1800s
  - 1852-1860: The third cholera pandemic
    - Snow showed the role of water in disease transmission
      - London's Broad Street pump (Broadwick St)
    - Miasma theory was discredited, but it

http://www.ph.ucla.edu/epi/snow/

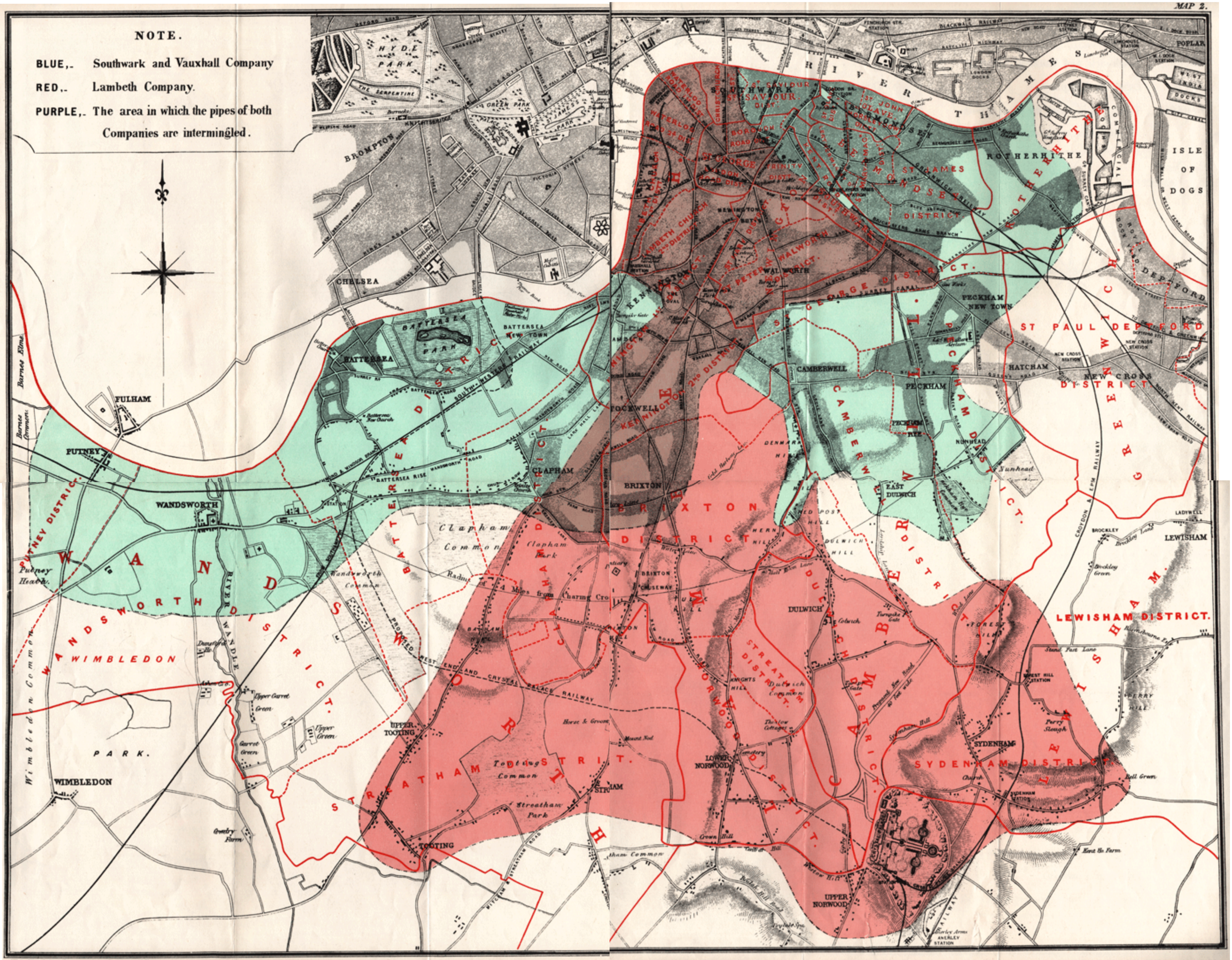


Soho, Westminster

Cluster Map of Fatal Cholera Cases in London, 1854

Source: Adapted from John Snow, *Snow on Cholera* (New York: Hafner, 1965).

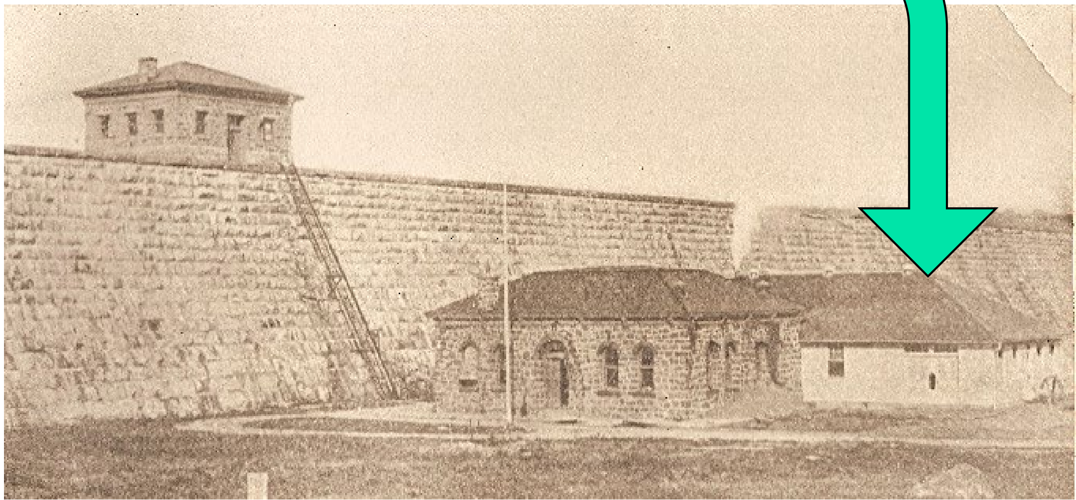
Picadilly Circus


MAP 2.
NOTE.
BLUE,- Southwark and Vauxhall Company
RED,- Lambeth Company.
PURPLE,- The area in which the pipes of both Companies are intermingled.
HYDE PARK
BROMPTON
CHELSEA
FULHAM
PUTNEY
WANDSWORTH
BATTERSEA
CLAPHAM
BRIXTON
WALWORTH
CAMBERWELL
PECKHAM
ROTHERHITHE
ISLE OF DOGS
POPLAR
RIVER THAMES
WIMBLEDON
PARK.
TOOTING
DULWICH
LEWISHAM
SYDENHAM
UPPER NORWOOD
LOWER NORWOOD
WANDSWORTH DISTRICT.
PUTNEY DISTRICT.
BATTERSEA DISTRICT.
CLAPHAM DISTRICT.
STREATHAM DISTRICT.
BRIXTON DISTRICT.
CAMBERWELL DISTRICT.
PECKHAM DISTRICT.
ST GEORGE DISTRICT.
LEWISHAM DISTRICT.
SYDENHAM DISTRICT.
NEW CROSS DISTRICT.
ST PAUL DEPTFORD
GREENWICH
ROTHERHITHE
BERMONDSEY
ST JAMES
ST SAVIOUR DIST.
WEST END AND CRYSTAL PALACE RAILWAY

John #2: Dr. John L. Leal

1858-1914

- Jersey City’s Boonton Reservoir
- Leal experimented with chlorine, its effectiveness and production
  - George Johnson & George Fuller worked with Leal and designed the system (1908)

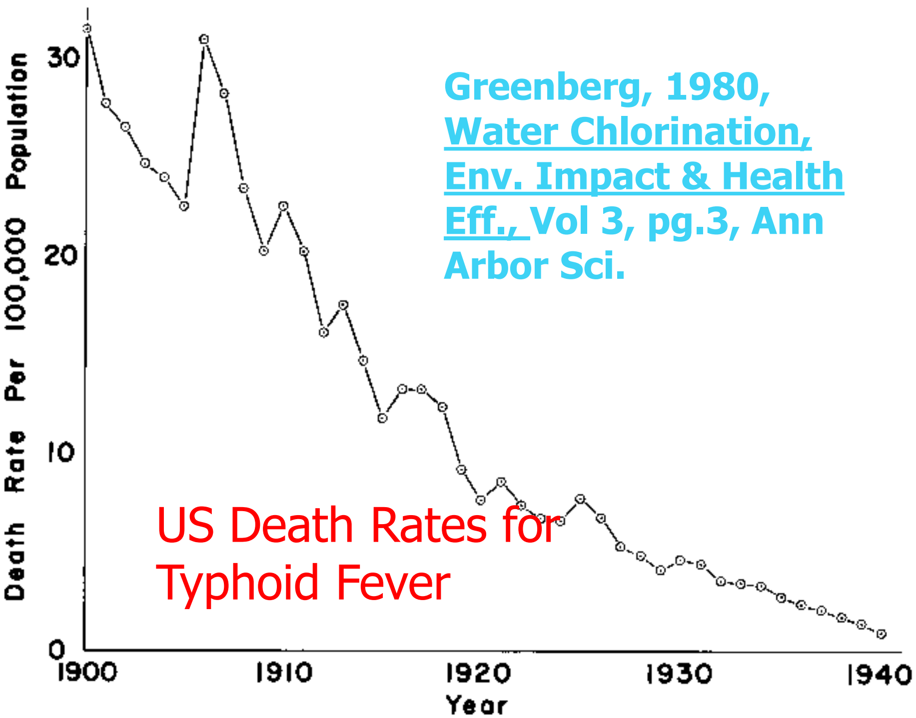


“Full-scale and continuous implementation of disinfection for the first time in Jersey City, NJ ignited a disinfection revolution in the United States that reverberated around the world”

M.J. McGuire, JAWWA 98(3)123

Chlorination

- 1-2 punch of filtration & chlorination



US Death Rates for Typhoid Fever

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

Melosi, 2000, The Sanitary City, John Hopkins Press

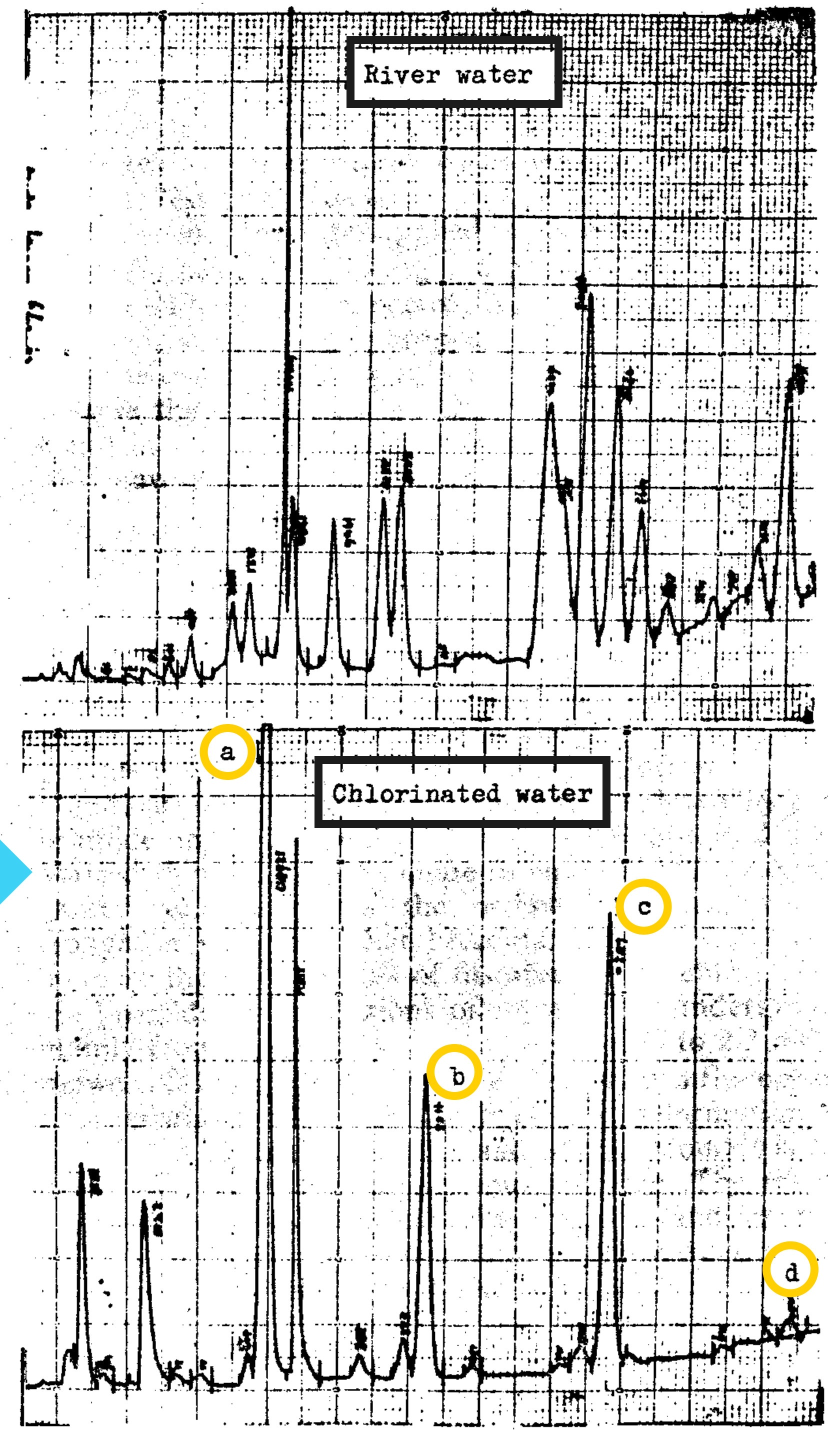
#3: Johannes J. Rook

- 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

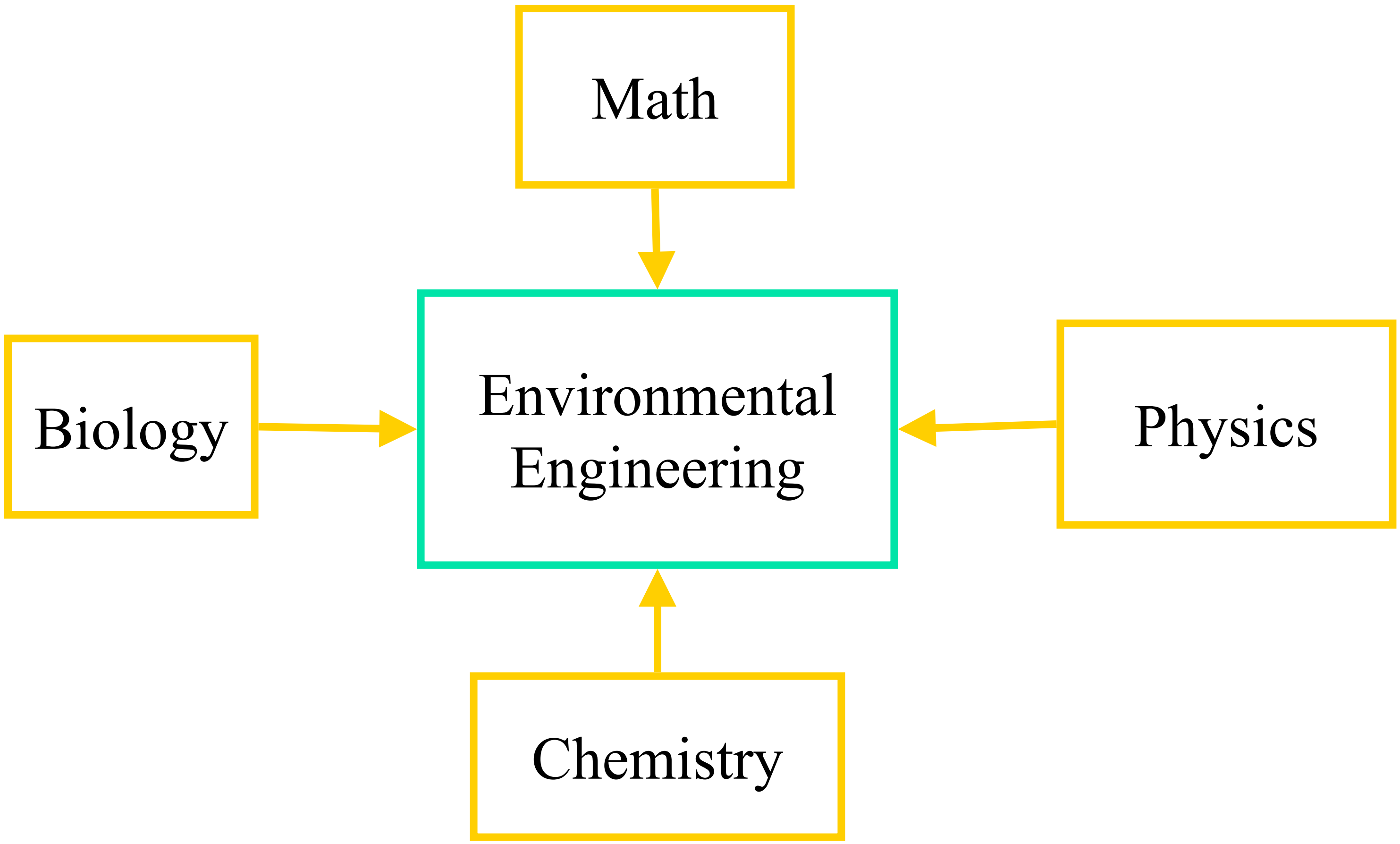
John Rook & DBPs

- Major Contributions
  - Brought headspace analysis from the beer industry to drinking water
    - T&O problems
  - Found trihalomethanes (THMs) in finished water
    - Carcinogens !?!
  - Published in Dutch journal H2O, Aug 19, 1972 issue
  - Deduced that they were formed as byproducts of chlorination
  - Proposed chemical pathways

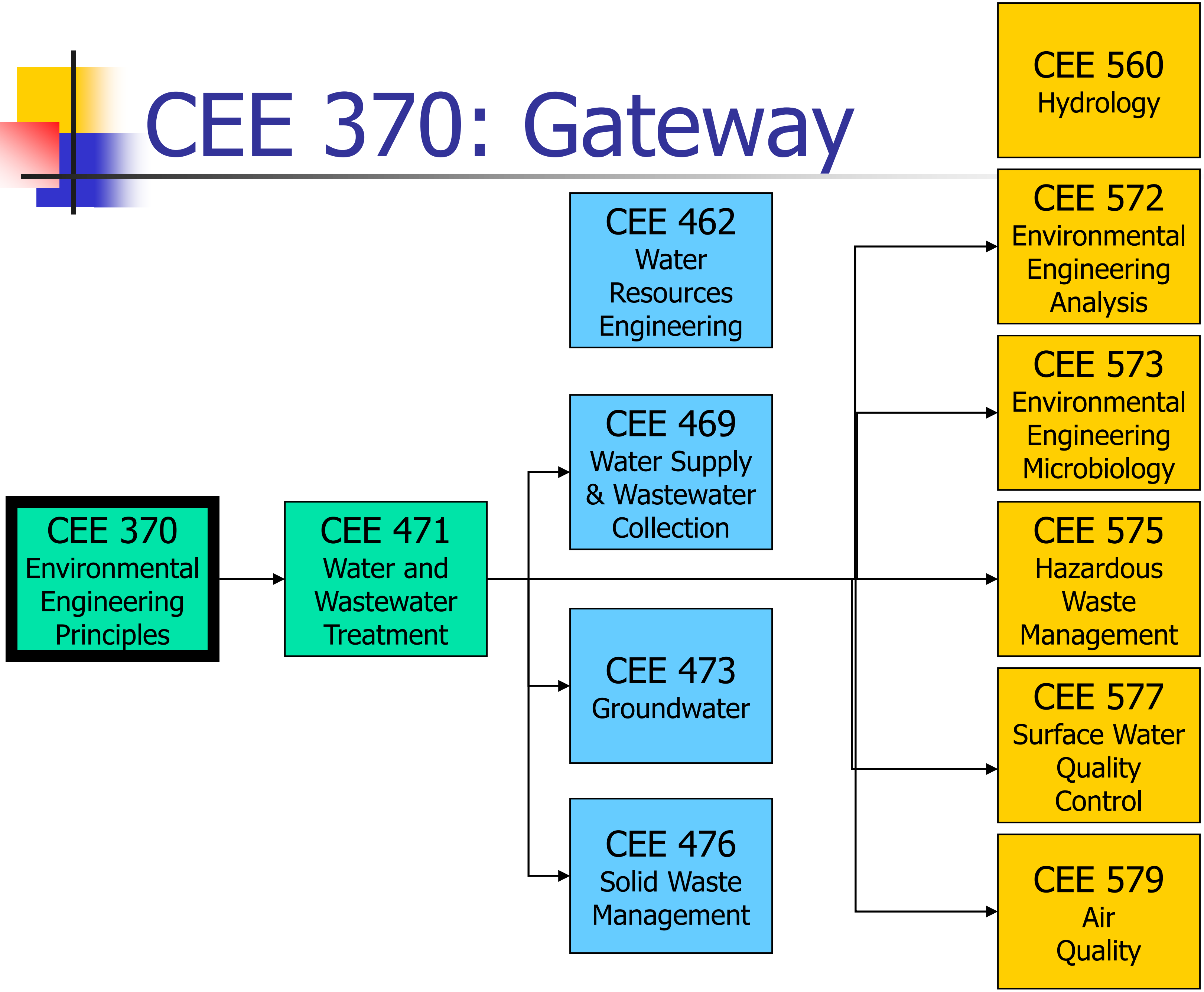
Rook, 1974, Water Treat. & Exam., 23:234



Environmental Engineering: Interdisciplinary



CEE 370: Gateway



What Environmental Engineers Do

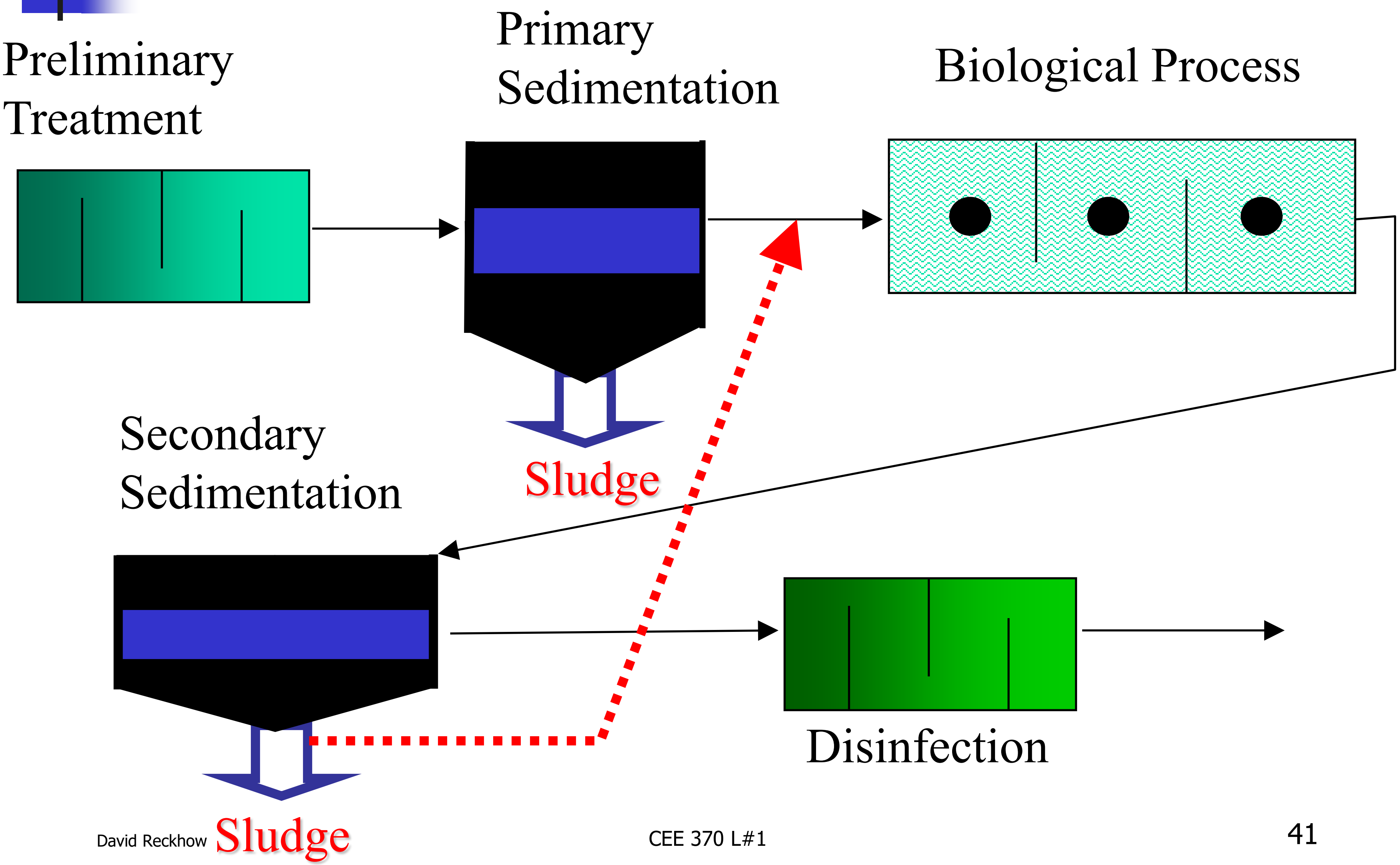
- Three examples
  - Water: Wastewater treatment
  - Air: Acid Rain
  - Solids: VOCs in Soils

Secondary Clarifiers

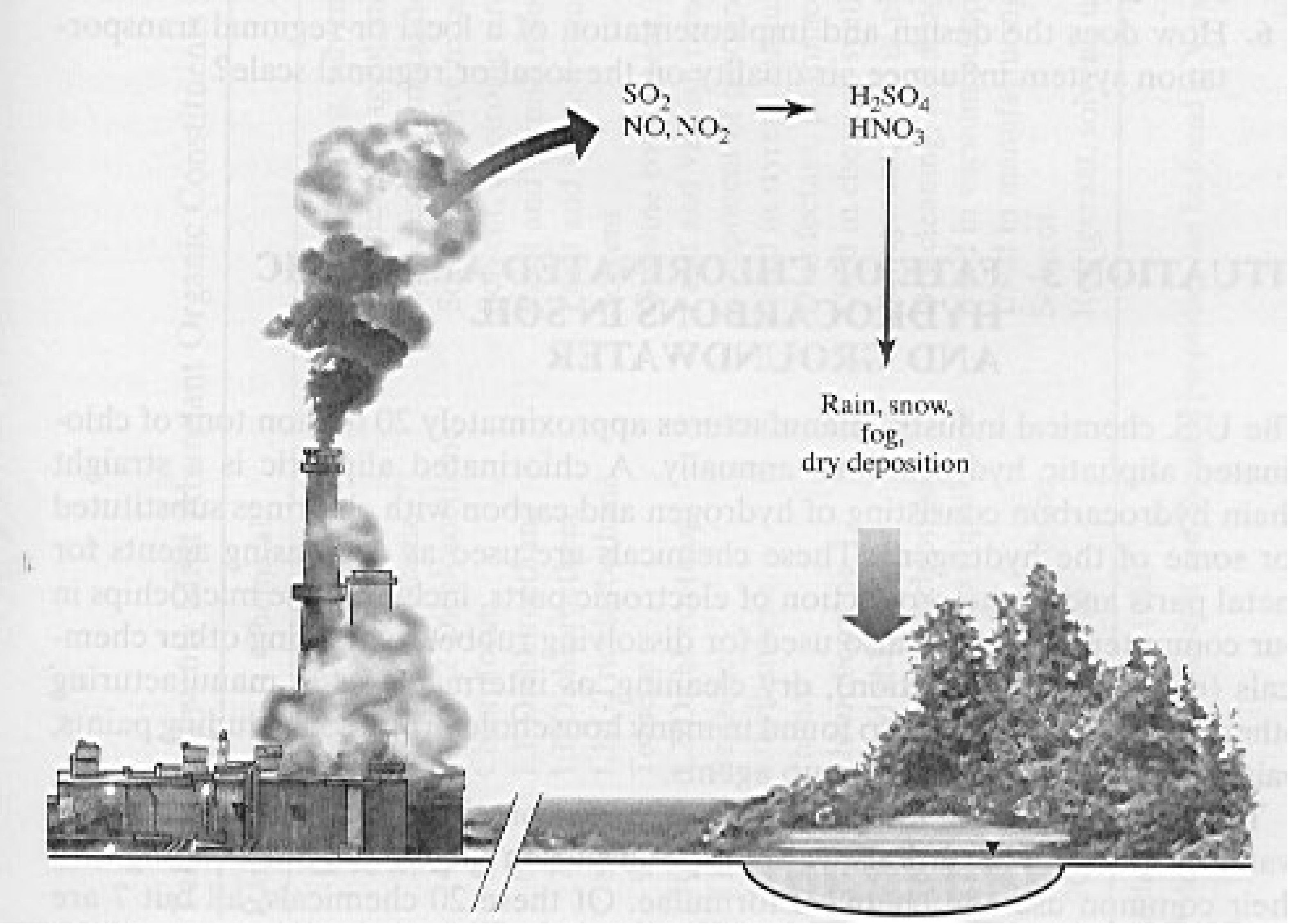
Situation #1: Municipal WWT

- Problem: you need to treat wastewater from a new suburban housing development
  - How do you design the plant?
    - Process types, tank sizes, N or P removal,
  - How do you operate the plant?
    - Treatment objectives, anaerobic or aerobic, seasonal variations, allow industrial users

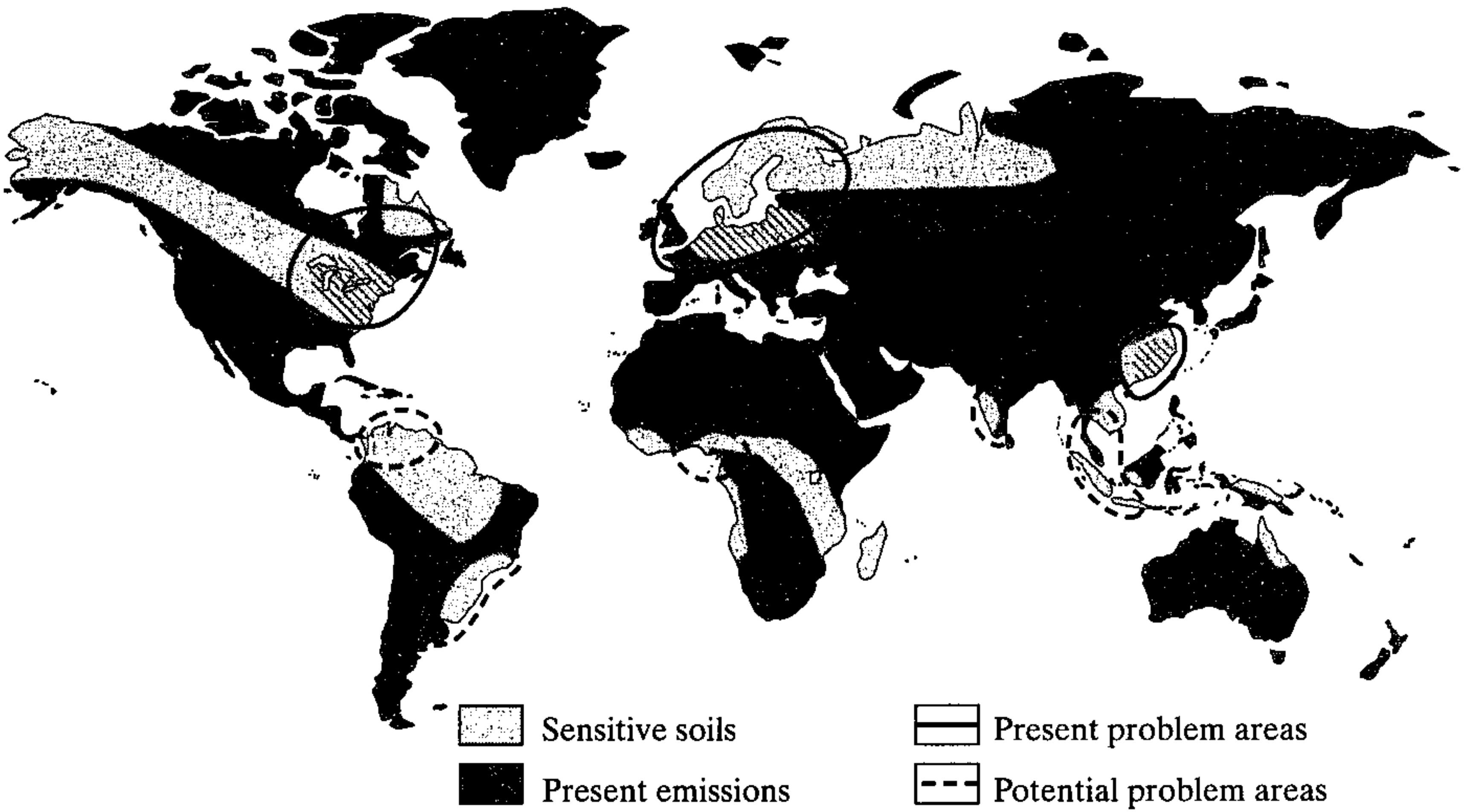
Conventional WW Treatment



Situation 2: Acid Rain



Global nature of acid rain



Air pollution issues

- How to remove sulfur and nitrogen oxides from stack gases
- What to do with the wastewater produced
- What happens with these gases get into the atmosphere
- How are the air pollution problems transported & who is affected
- What impact do these emissions have on natural water and aquatic life
- Regional solutions

Situation 3: VOCs in Soil

- Design & operation of treatment system
  - For soil, sediment, groundwater, leachate
- What type of system
  - Chemical, biological, physical
- What is the fate of the VOCs
- How quickly will they spread
- Will they form more toxic byproducts
  - Trichloroethene to vinyl chloride

Rank	Chemical	Use	Chemical Formula
1	Dichloromethane	Paint stripping, solvent degreaser, blowing agent in foams	CH_2Cl_2
2	Trichloroethene	Dry cleaning agent, metal degreaser solvent	C_2Cl_3H
3	Tetrachloroethene	Dry cleaning, metal degreaser, solvent, paint remover	C_2Cl_4
4	*trans* 1,2-Dichloroethene	Solvent, additive to lacquer, low-temperature solvent for caffeine	$C_2H_2Cl_2$
5	Chloroform	Solvent, electronic circuit manufacturing	$CHCl_3$
6	l,1-Dichloroethane	Paint and varnish remover, metal degreaser, ore flotation	$C_2C1_2H_4$
7	1,1-Dichloroethene	Paint and varnish remover, metal de-greaser	$C_2C1_2H_2$
8	1,1,1-Trichloroethane	Solvent	$C_2Cl_3H_3$
9	Toluene	Gasoline component, solvent thinner, adhesive solvent	C_7H_8
10	1,2-Dichloroethane	Paint and varnish remover, metal degreaser, fumigant	$C_2C_{12}H_4$

Rank	Chemical	Use	Chemical Formula
11	Benzene	Component of gasoline, used in chemical synthesis	C_6H_6
12	Ethylbenzene	Used in styrene manufacturing, solvent, asphalt construction	C_8H_{10}
13	Phenol	Disinfectant, pharmaceutical aid	C_6H_5OH
14	Chlorobenzene	Used in chemical synthesis	C_6H_5Cl
15	Vinyl chloride	Refrigerant, used in plastics industry	C_2ClH_3
16	Carbon tetrachloride	Dry cleaning, metal degreasing, veterinary medicine	CCl_4
17	Bis(2-ethylhexyl)phthalate	Used in vacuum pumps	$C_{24}H_{38}O_4$
18	Naphthalene	Used in manufacturing mothballs and motor fuel, component of coal tar	$C_{10}H_8$
19	1,1,2-Trichloroethane	Solvent	$C_2Cl_3H_3$
20	Chloroethane	Refrigerant, solvent, used to produce tetraethyl lead	C_2ClH_5

- How can we use our knowledge of physical & chemical properties?

Table 1-2. Properties of Selected Chlorinated Aliphatic Hydrocarbons*

Chemical	Vapor Pressure (mmHg)	Henry's Constant (atm-m^3/mole)	Water Solubility (mg/L)	Chemical Half-life (Years)
Carbon tetrachloride	90	0.0294	785	16–41
Chloroform	160	0.0040	8,200	742–3,000
Tetrachloroethene	14	0.0268	150	3.8×10^8–9.9×10^8
Trichloroethene	60	0.0117	1,100	4.9×10^5–1.3×10^6
Vinyl chloride	2,660	0.0224	2,700	>10

From Barbee, 1994.

*In later chapters, readers will learn about how these properties are used in evaluating and solving environmental problems.

From: Mihelcic, 1999

Information Sources

Field	Journal	Publisher
Environmental quality	*Environmental Science and Technology*	American Chemical Society
	Water Resources Research	American Geophysical Union
	Water, Air and Soil Pollution	Kluwer Academic Publications
Water treatment	*Journal of the American Water Works Association*	American Water Works Association
	Aqua	International Water Assn.
	Journal of the Environmental Engineering Division	American Society of Civil Engineers
Wastewater treatment	*Water Environment Research*	Water Environment Federation
	Journal of the Environmental Engineering Division	American Society of Civil Engineers
Solid waste	*BioCycle*	J. G. Press, Inc.
Hazardous waste	*Hazardous Waste and Hazardous Materials*	Mary Ann Liebert, Inc.
	Ground Water	Ground Water Publications, Inc.
Air pollution and control	*Journal of the Air and Waste Management Association*	Air and Waste Management Association
General	*Chemical and Engineering News*	American Chemical Society
	Civil Engineering	American Society of Civil Engineers

Books

- General Environmental Principles
  - Course text & supplementary references
- Water & Wastewater Treatment
  - Hammer & Hammer (or CEE 371 text)

•Government Sources

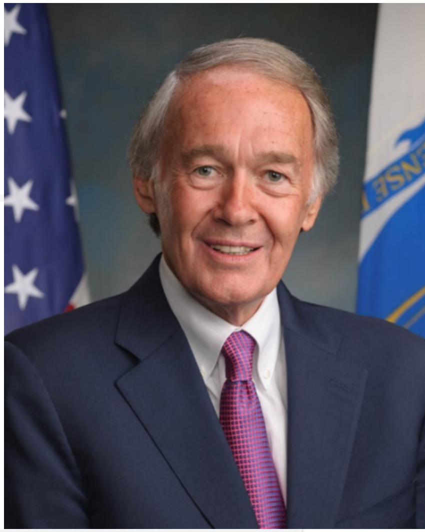
Source	Telephone Number	Address
Center for Environmental Research Information (CERI)	(513)569-7562	ORD Publications P.O. Box 19962 Cincinnati, OH 45219-0962
Superintendent of Documents	(202) 783-3238	Superintendent of Documents Government Printing Office Washington, DC 20402
RCRA Docket Information Center (RIC)	(800) 424-9346	RCRA Docket Information Center (RIC) Office of Solid Waste (OS-305) U.S. Environmental Protection Agency 401 M Street, S.W. Washington, DC 20460
National Technical Information Service (NTIS)	(703) 487-4650	National Technical Information Service U.S. Department of Commerce Springfield, VA 22161 Washington, DC

Laws and Regulations

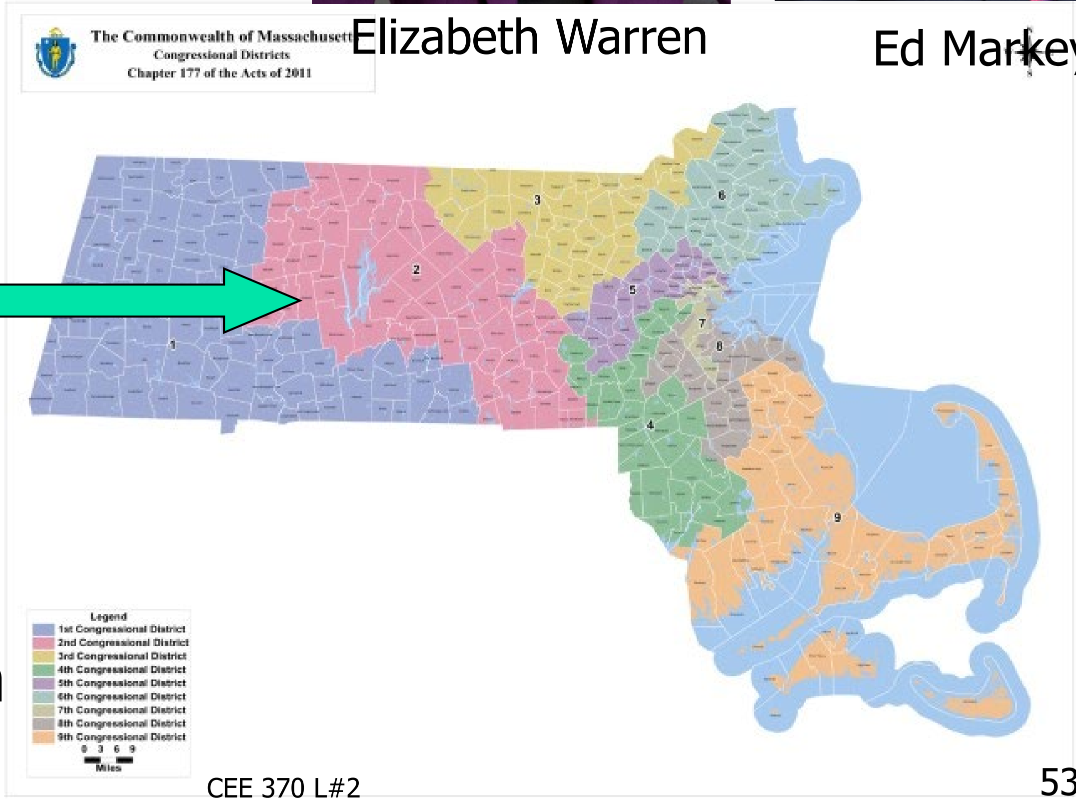
- Laws: passed by a majority of both *legislative* houses and signed by the President
- Regulations: established by *executive* branch (USEPA) in response to laws
  - propose in Federal Register
  - public comment and modification
  - promulgation: into Code of Federal Regulations (CFR Part 40)

Our Delegation

Elizabeth Warren



Ed Markey



- House
  - James McGovern

1972: Federal Water Pollution Control Act

An "act" of Congress = a law

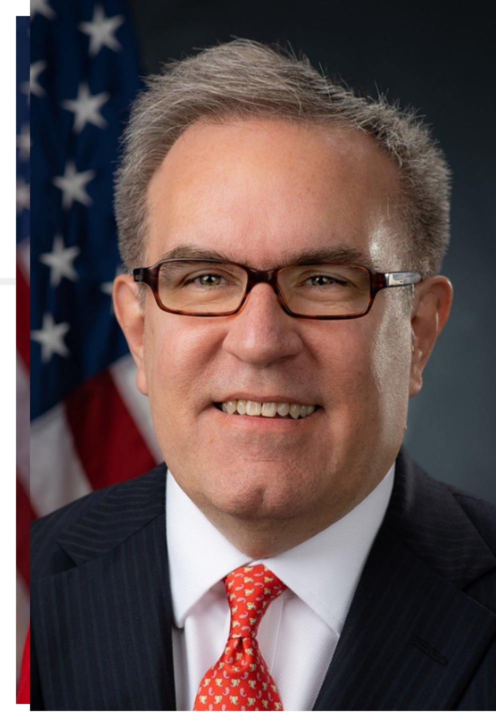
- PL 92-500 subsequently amended and now called the Clean Water Act
  - established water quality goals "fishable & swimmable" and timetable
  - established National Pollution Discharge Elimination System (NPDES)
  - construction grants for WW treatment
- Eventually required secondary treatment (30/30)
  - 30 mg/L BOD_5
  - 30 mg/L TSS

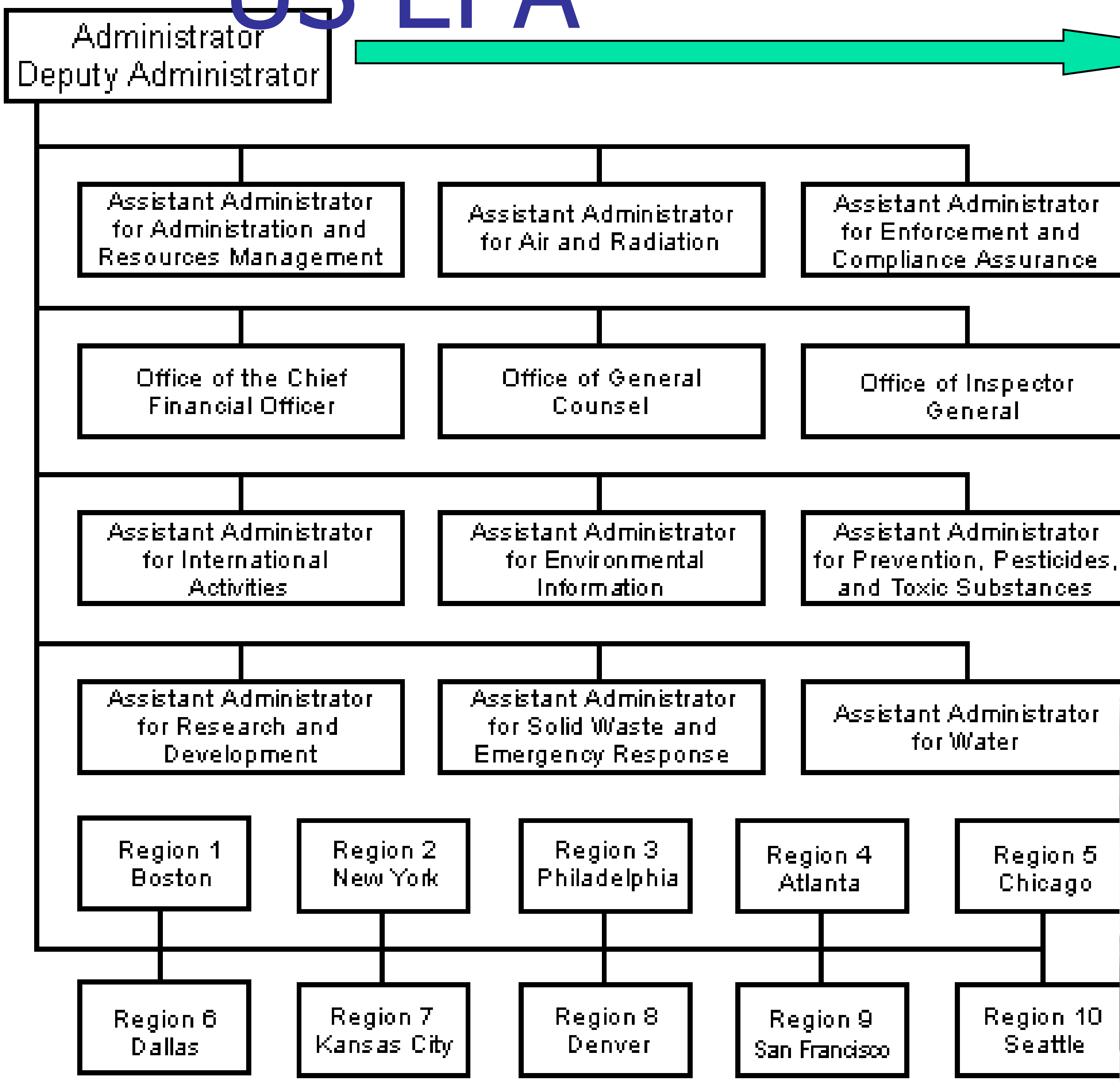
Laws: where to find them

- Daily
  - Federal Register
    - Back to 1994: on-line
      - http://www.gpoaccess.gov/fr/index.html
    - Pre 1994: see Gov Docs in DuBois
- Annual summary (July)
  - Code of Federal Regulations (CFR)
    - Back to 1996/7: on-line
      - http://www.gpoaccess.gov/cfr/index.html
    - Pre 1996/7: see Gov Docs in DuBois

US EPA

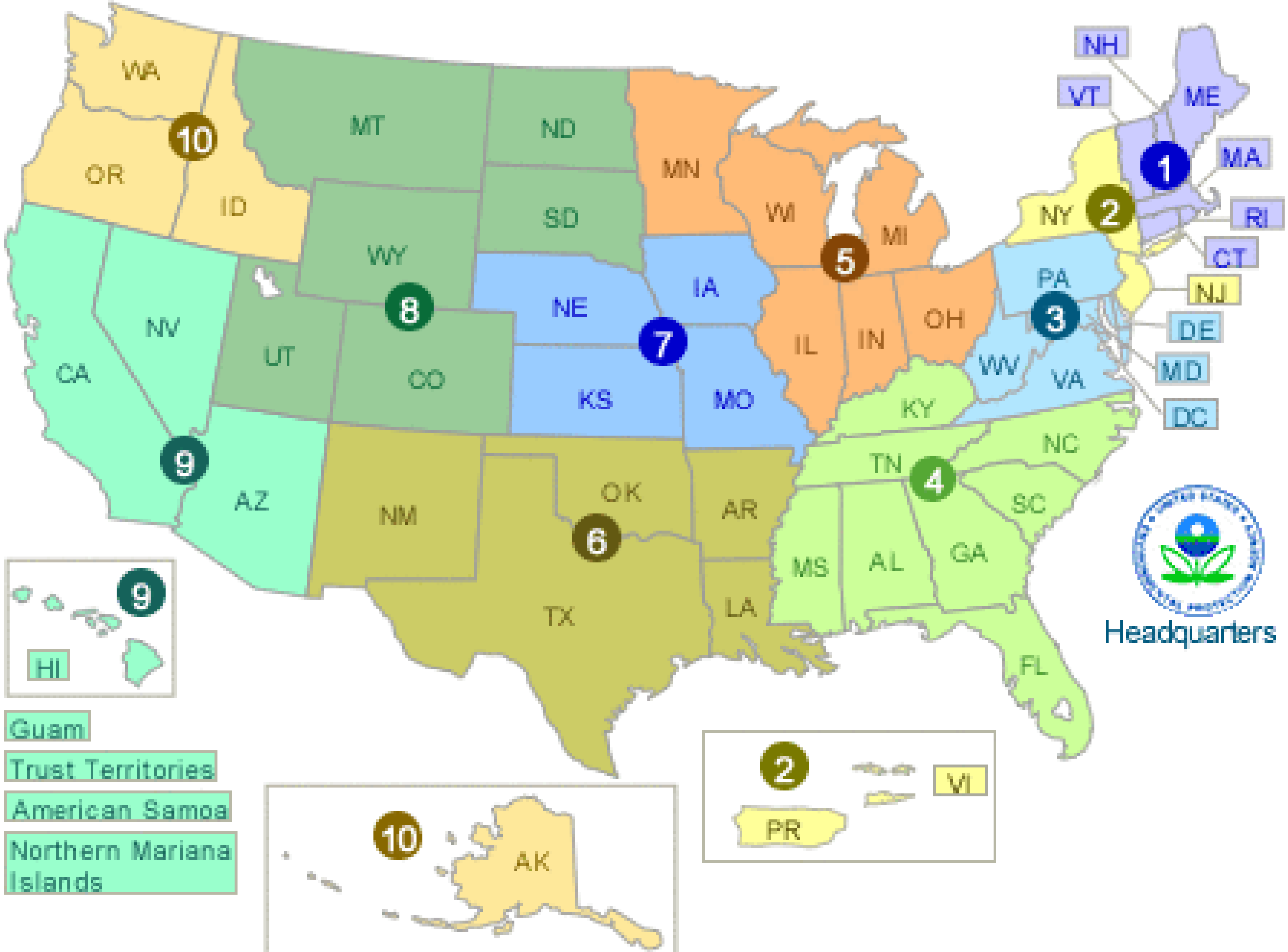
Andrew Wheeler





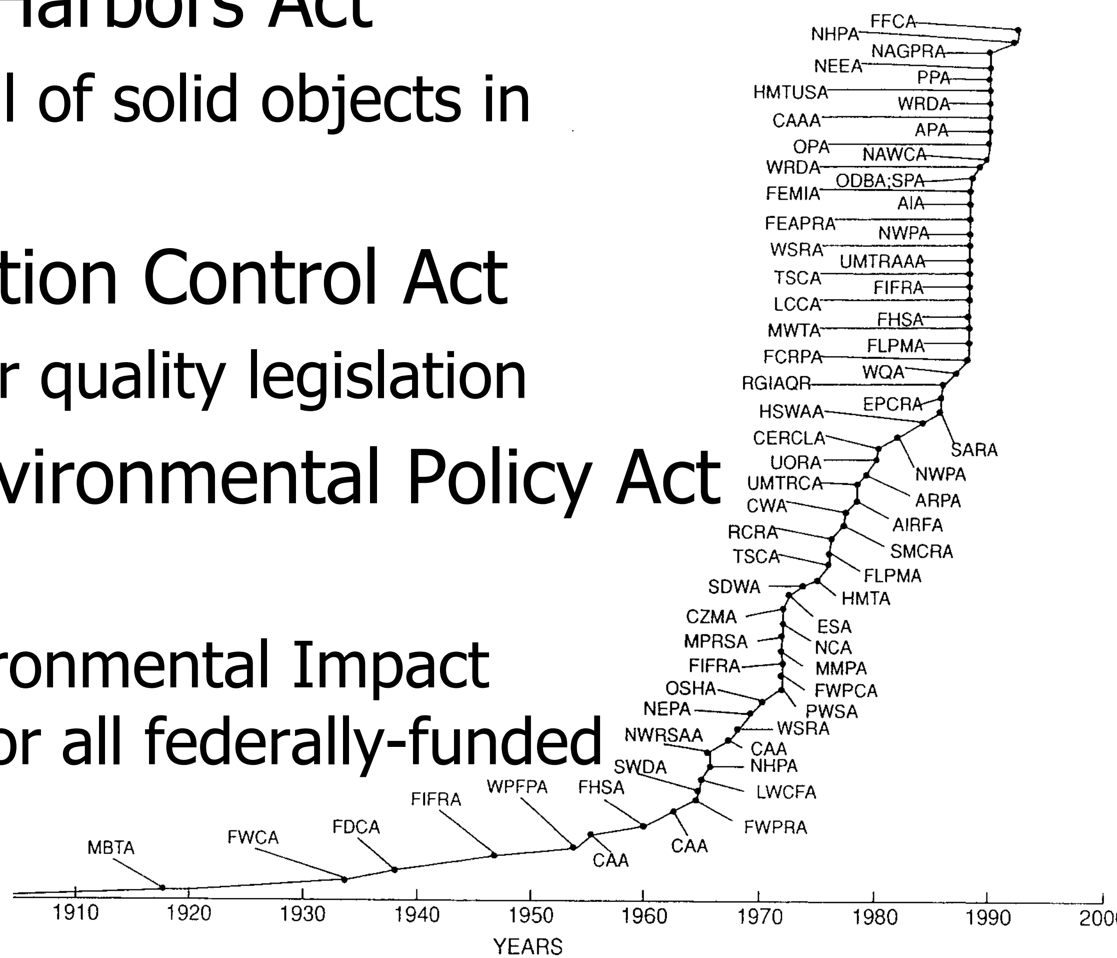
- Created by Nixon Adm

USEPA Regions



Legislative History

- 1899: Rivers and Harbors Act
  - Prohibited disposal of solid objects in navigable waters
- 1948: Water Pollution Control Act
  - first national water quality legislation
- 1970: National Environmental Policy Act (NEPA)
  - required and Environmental Impact Statement (EIS) for all federally-funded projects



FEDERAL ENVIRONMENTAL LEGISLATION

Legislative History

- 1970: USEPA formed
- 1972: Federal Water Pollution Control Act
  - PL 92-500 subsequently amended and now called the Clean Water Act
  - established water quality goals "fishable & swimable" and timetable
  - established National Pollution Discharge Elimination System (NPDES)
  - construction grants for WW treatment
  - Required industry-specific WW treatment technology
    - BPT: best practicable technology by 1977
    - BAT: best available technology by 1983

Legislative History (cont.)

- 1970: Clean Air Act
  - national air quality standards
  - amended several times since ('77 '90)
- 1974: Safe Drinking Water Act
  - set national drinking water standards
  - amended may times since
- 1976: Toxic Substances Control Act (TSCA)
  - regulate new hazardous chemicals (e.g. PCBs)

Legislative History (cont.)

- 1976: Resource Conservation and Recovery Act (RCRA)
  - protect air, water and land from solid and hazardous wastes
  - defines hazardous wastes
- 1977: Clean Water Act Amendments
  - Best conventional pollutant technology (BCT)
  - Secondary treatment: 30 mg/L BOD_5 30 mg/L TSS
  - Priority Pollutants (127 toxic compounds)
- 1980: Comprehensive Environmental Response, Compensation and Liabilities Act (CERCLA or Superfund)
  - established fund and mechanisms for cleaning existing hazardous waste sites

Regulatory Methods

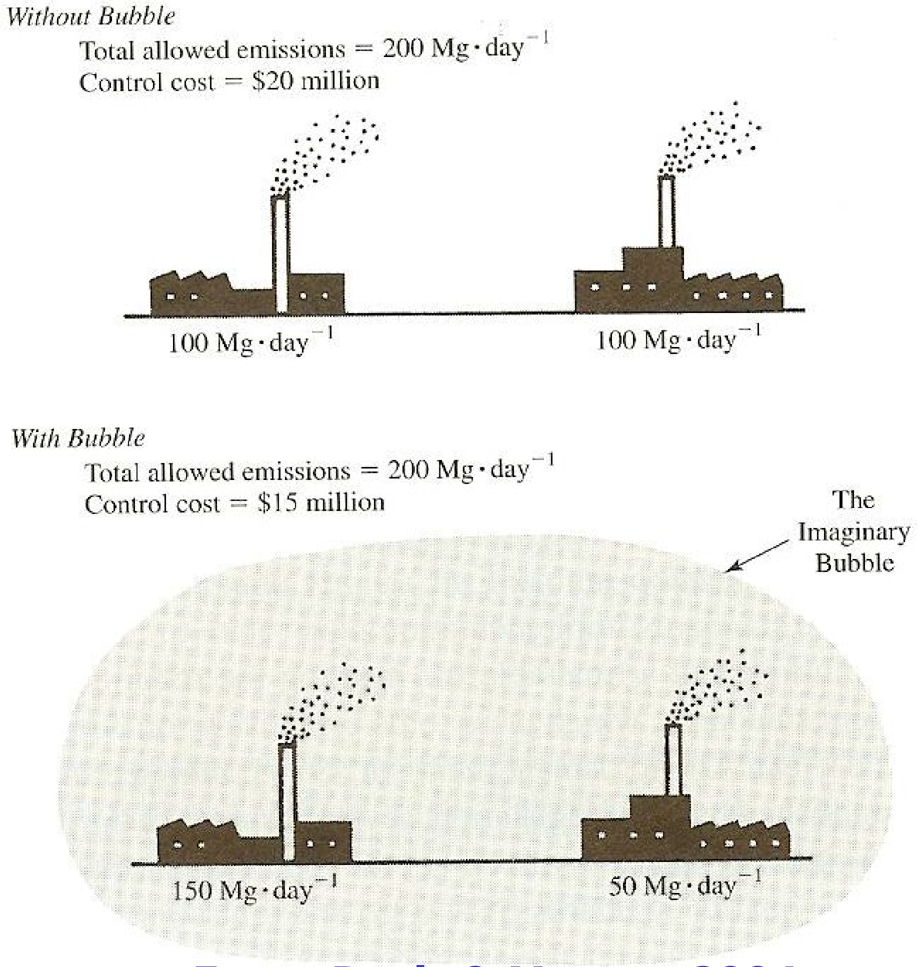
- Environmental Quality-Based Standards
  - cannot degrade environment beyond a certain level
  - dependent on immediate environment
  - more flexible
- Effluent-Based Standards
  - cannot discharge above a certain level of pollutant
  - independent of immediate environment
  - easier to establish and monitor

“Controlled Trading”

- Bubble Policy

"Environmental rules now regulate each of the different processes in a plant. With this new policy we will draw an **imaginary bubble** around the whole plant and tell the company that it can find the most efficient way of controlling the plant's emissions as a whole. If it costs a dollar to control a pound of particulate pollution from one machine and fifty cents from another, the plant manager will quite reasonably choose to control fewer $1 pounds and more 50 cent pounds. If the plant engineer can find a new way of reducing particulate emissions from a third machine for 30 cents a pound, he will remove as many of these pounds as he can in preference to either the 50 cent or one dollar pounds. As long as no more particulates escape from the overall bubble than before, the company's engineers can continue to innovate."

Douglas Costle, EPA Administrator, 1979



From: Davis & Masten, 2004

Controlling Air Pollution in Cities

Source	Pollutants	Methods of Control
Industries	Volatile organics	Require reduced emissions
	Volatile chlorofluorocarbons	Require reduced emissions
	Particulate inorganics	Require reduced emissions
Automobiles	Hydrocarbons	Improved discharge nozzles at filling stations, improved ventilation within the gasoline tank
	Products of incomplete combustion	Improved combustion by requiring improved combustion efficiency (auto manufacturer), regular engine maintenance by requiring vehicle emission testing, requiring gasoline stations to provide only oxygenated fuels.
	Chlorofluorocarbons from air conditioners	Require the redesign of the air conditioner so that future automobiles can use other refrigerants.

Table 2.2 in Ray (pg 18)

Basis for Setting Standards

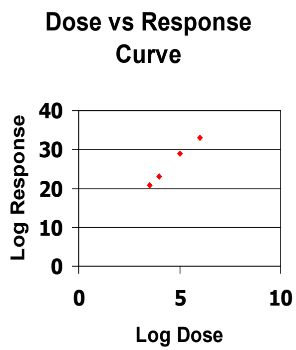
- Experimentation
  - animal testing, human exposure
- Attainability
  - economic & technical feasibility
- Established practice
- Risk Assessment

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

Four steps in a Risk Assessment

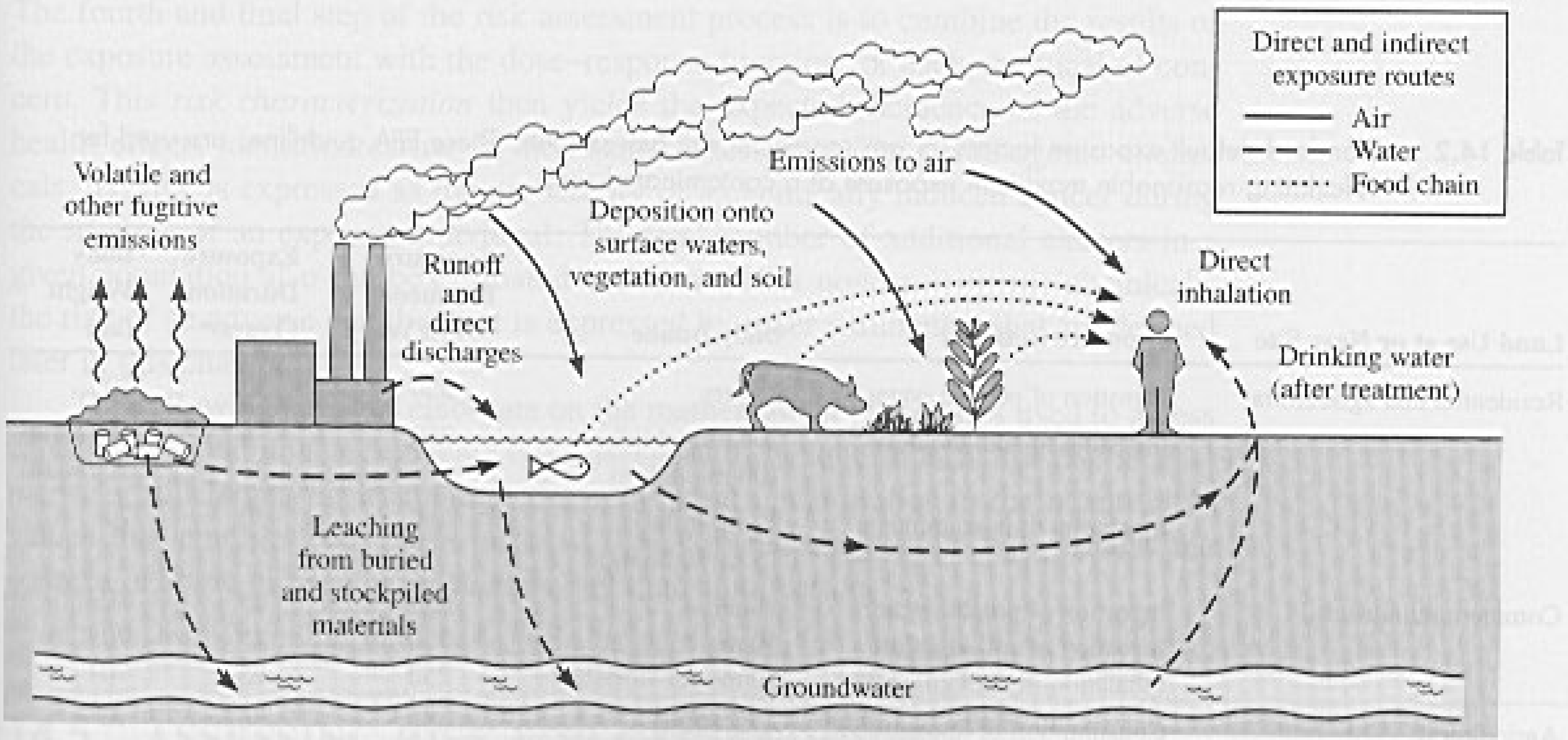
- Hazard Identification
  - what is it?
- Dose Response
  - see graph
- Human Exposure
  - actual doses and routes
- Risk Characterization



Region of uncertainty

Routes of exposure

From: Rubin, 2001



Comparative Risks

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

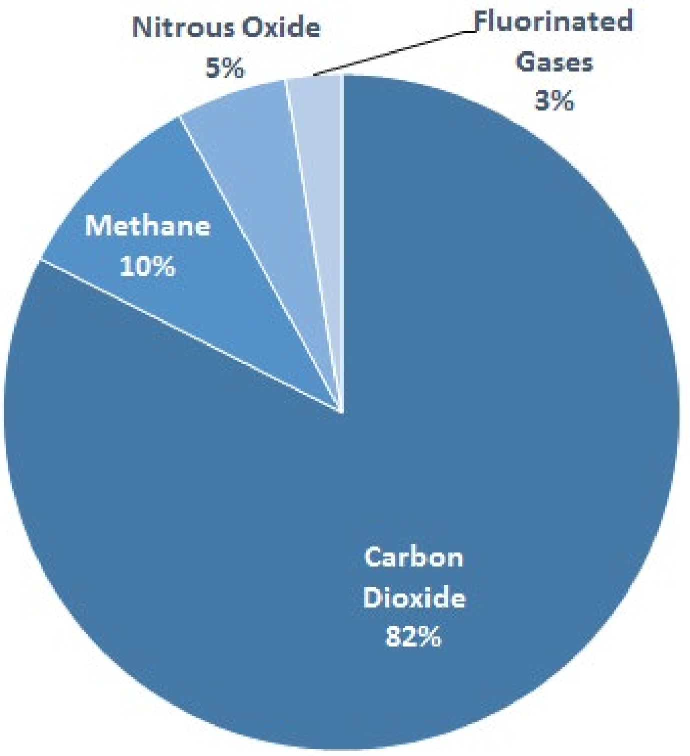
Next

- To next lecture

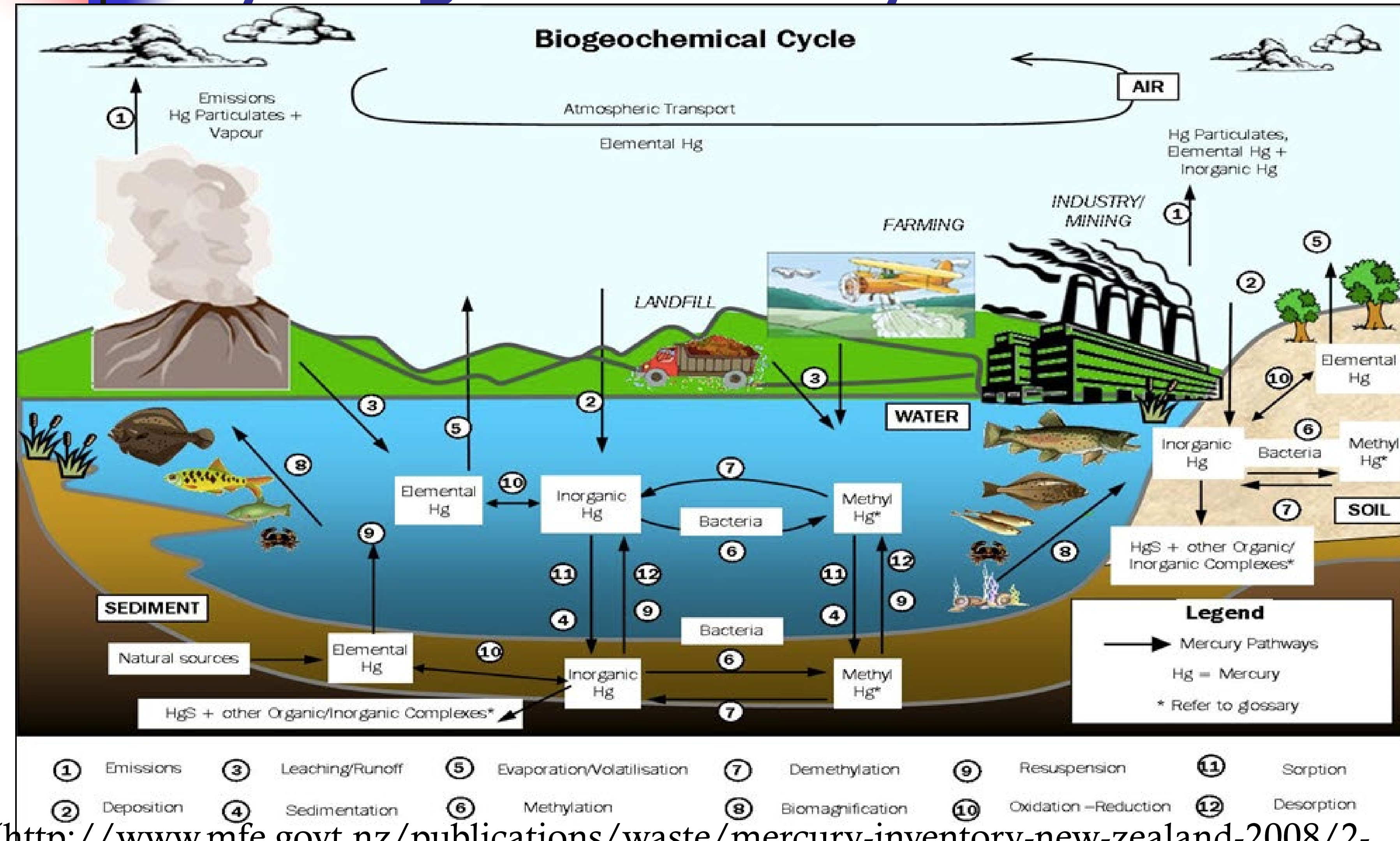
- Reading for next class
  - Mihelcic & Zimmerman, Chapter 2

Main Umbrellas - Air

- Air pollution
  - Acid rain
  - Greenhouse gases
  - CO
  - Particulate matter
  - O_3 at the ground level
  - Pb
  - Nitrogen oxides
  - Sulfur oxides
- Indoor air quality
  - CO
  - Radon
  - Mold and moisture



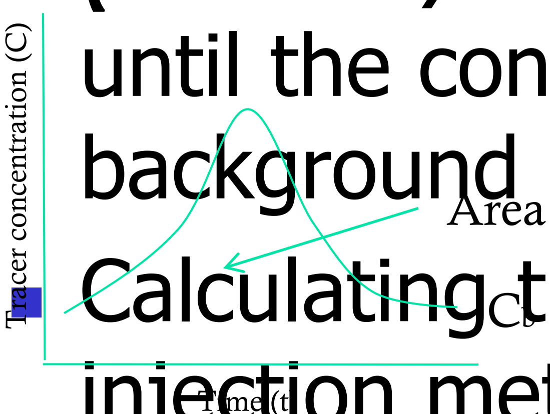
Cycling of Mercury



(http://www.mfe.govt.nz/publications/waste/mercury-inventory-new-zealand-2008/2-mercury-environment)

Tracer-Dilution Method (Instantaneous)

- A measure of the downstream concentration of a tracer (known volume and concentration) discharged/injected ***instantaneously (sudden/slug)*** upstream over time until the concentration reaches the background level.



$$Q\left(\frac{L^3}{t}\right) = \frac{C_t V_t}{\int_0^\infty (C - C_b)\,dt} = \frac{C_t V_t}{area\ under\ curve}$$

- Calculating the discharge from the slug injection method involves integration,