

GEOS 3310 Lecture Notes: Water Pollution

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Water Pollution

Introduction

Water pollution is the “degradation of water quality as measured by biological, chemical, or physical criteria.” Common sources of groundwater pollution are listed in Keller [Table 14.3, 2011]. Typical pollutants include:

- Oxygen-demanding waste: materials that produce a high BOD [Fig. 11.2, Keller, 2000]
- Pathogens: disease-causing microorganisms
- Nutrients
 - often lead to *eutrophication* [Fig. 14.6a-c, Keller, 2011].
 - see Gulf “Dead Zone” below and worldwide map of reported dead zones

- Oil: e.g Exxon Valdez spill, BP Macondo Well blowout
- Toxic chemicals: organic compounds, heavy metals (e.g. mercury), radioactive material
- Sediments: our greatest pollutant by volume
- Heat: cooling-tower water discharge can produce significant environmental change, beneficial if planned (e.g. Lake Konawa, OK)

Gulf of Mexico Dead Zone

The most severe nutrient pollution issue in U.S. is Gulf Coast “*Dead Zone*” (Fig. 1), with Chesapeake Bay a close second.

- high nutrient loads in Mississippi River discharge (USGS Circular) lead to large algal blooms see NOAA animation)
- seasonal stratification leads to hypoxia zone, killing marine life (Fig. 2) and Baltic images
- Gulf Dead Zone steadily growing , (see also LSU Current Status webpage)
- problem source
 - this is an example of a distributed (“*non-point*”) source

- depends on land-use [Fig. 11.3, Keller, 2000]
- e.g. increased corn production for ethanol may cause larger dead zone, see CNN story)
- similar hypoxia from nitrate in groundwater in Cape Cod
- hurricanes can intermittently reduce dead zone area by re-aerating deeper waters

Gulf Dead Zone

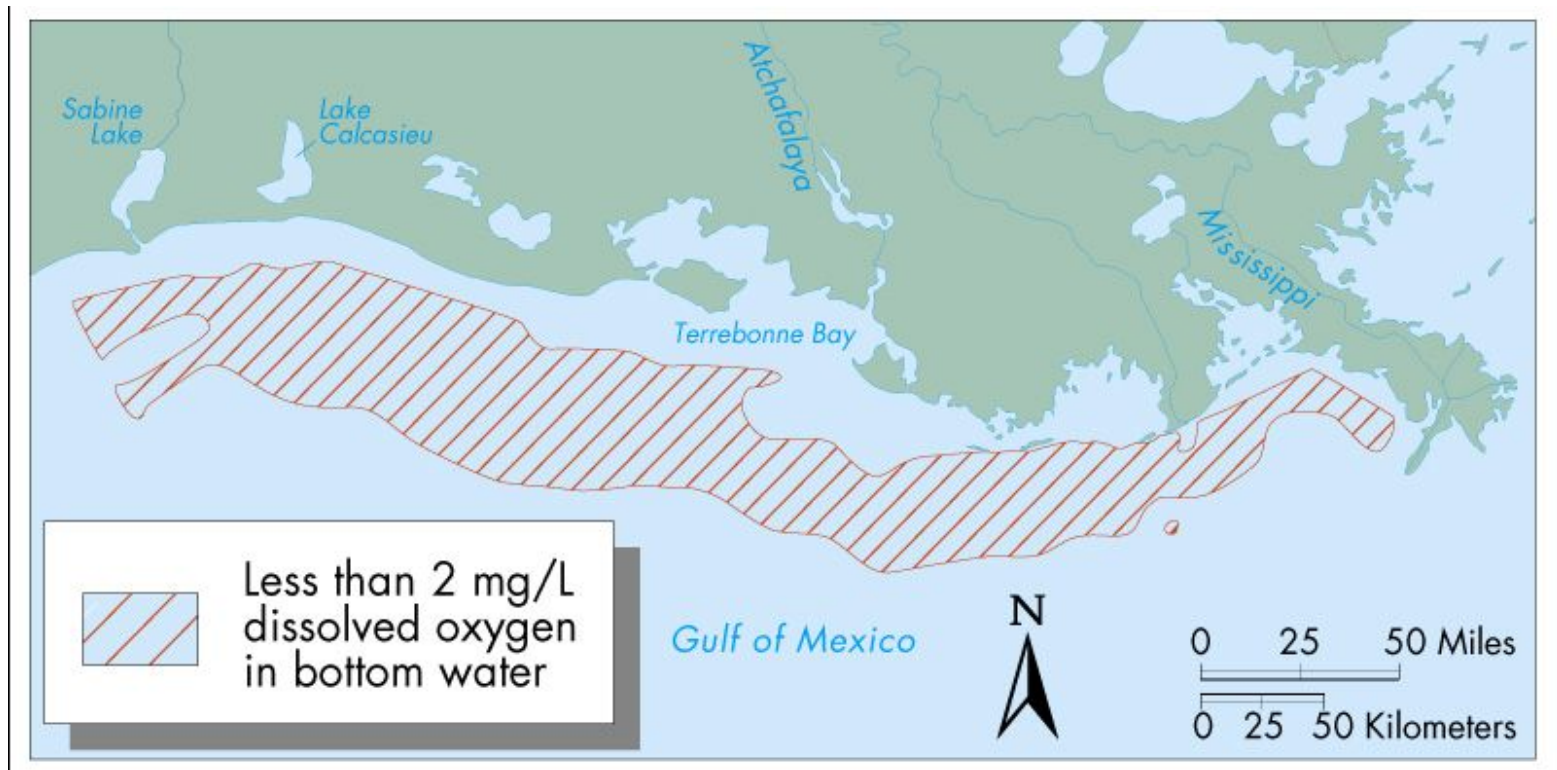


Figure 1: Gulf of Mexico nitrate-generated “Dead Zone”, a byproduct of increased nitrate discharge from Mississippi River. Annually in summer this zone develops, and has been growing with time [Fig. 14.7, Keller, 2011].

Gulf Hypoxia Mechanism

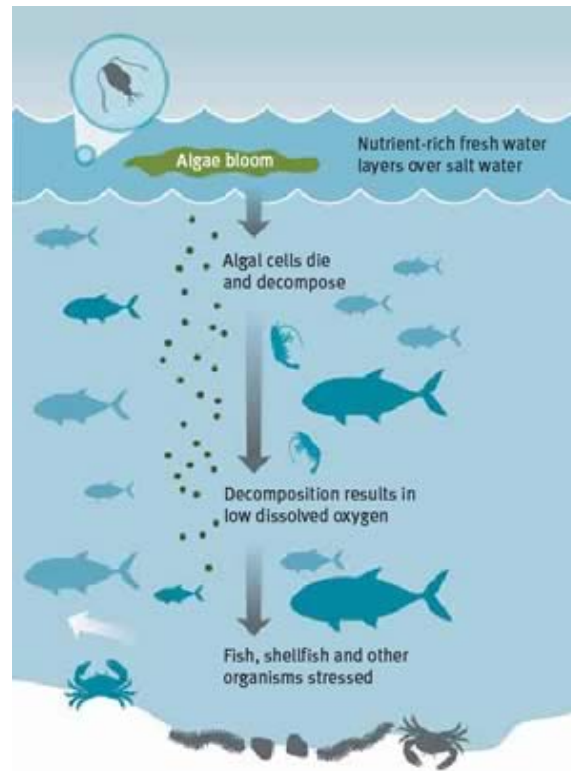


Figure 2: Mechanism of formation of Gulf of Mexico “Dead Zone”. After Louisiana Coastal Project . See also more detailed depiction .

Increasing Nitrates to Gulf

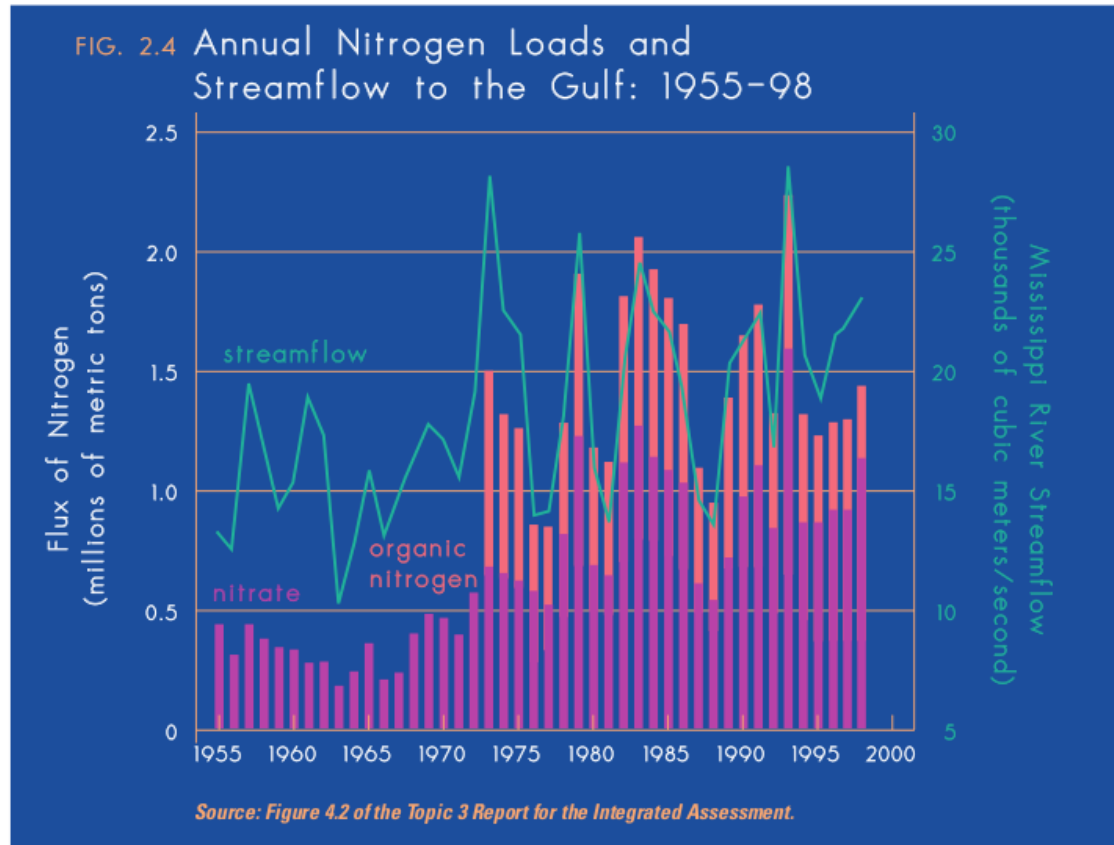


Figure 3: Gulf of Mexico nitrate load vs. time [CENR, 2000, Fig. 2.4].

Agricultural Nitrate Source

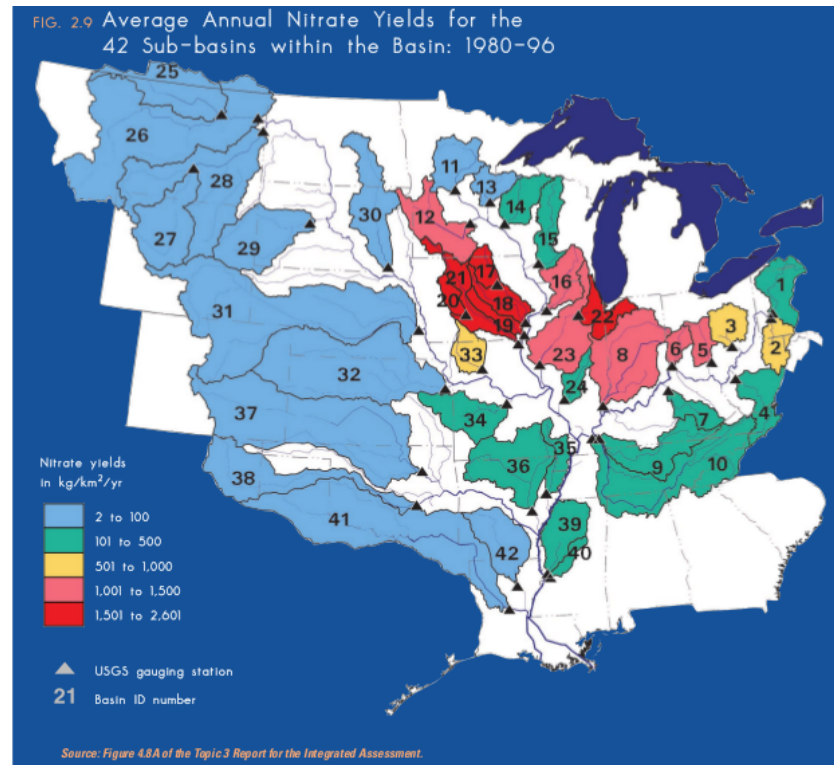


Figure 4: Nitrate load by sub-basin, Mississippi River. “The principal sources of nitrate are river basins that drain agricultural land in southern Minnesota, Iowa, Illinois, Indiana, and Ohio, where large amounts of nitrogen are applied to corn and soybean fields.” [CENR, 2000, Fig. 2.9]. See also USGS 1980-2008 summary .

Pollution Source Types

- two main categories of source:
 - *point*: discrete and confined, e.g. pipes or discharge from a single facility. Relatively easy to find and control
 - *non-point*: distributed, often cumulative effects of runoff from cities or farms. Harder to isolate and control.
- Reduction of pollution [Fig. 11.9, Keller, 2000]
 - many initiatives, partly embodied in the Clean Water Act, have reduced point sources of pollution
 - those laws inspired by severe cases like Cuyahoga River fires resulting from severe pollution
 - most important has been the establishment of *Maximum*

Contaminant Levels for drinking water [Table 14.5, Keller, 2011]

- non-point sources are beginning to be controlled through widespread monitoring, e.g. all cities larger than 100,000 people must report storm-water quality (street runoff)
- ultimately the most likely paths for movement of pollution into surface and groundwater must be identified and controlled (Fig. 5)

Pollution Pathways

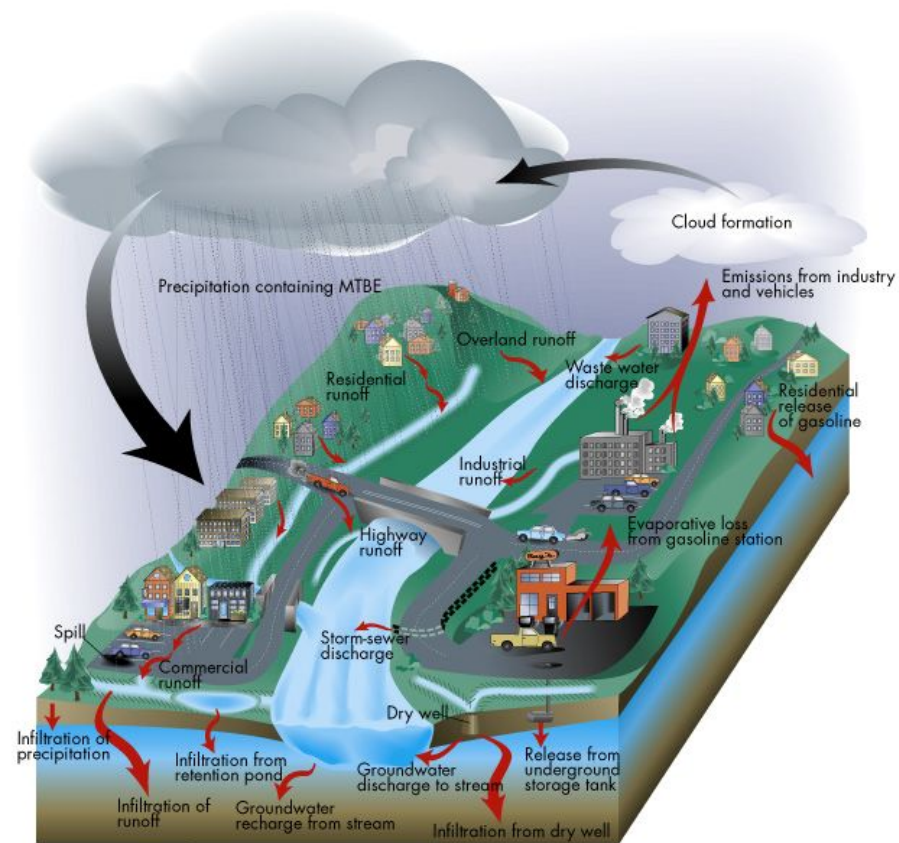


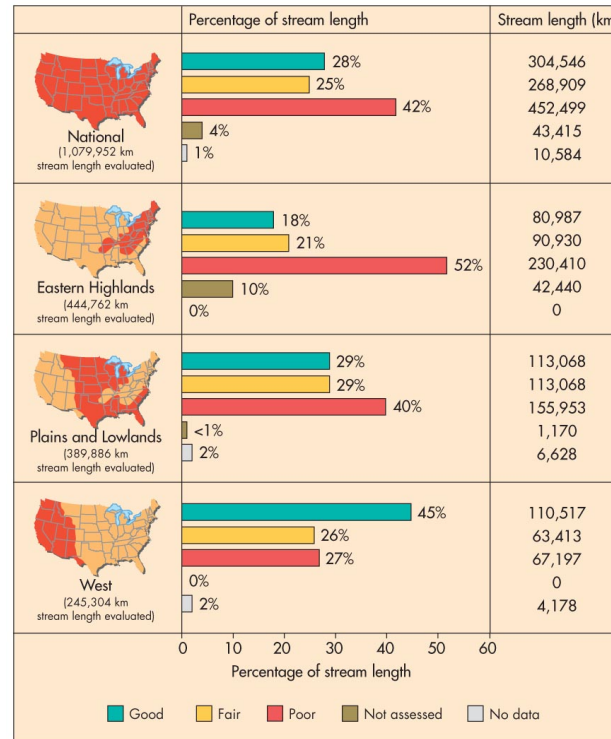
Figure 5: Potential pathways for migration of pollutants into ground and surface water [Fig. 14.5, Keller, 2011].

Seawater Intrusion

- all island, most coastal and some inland aquifers have a lens of freshwater floating on seawater
- excess pumping of the freshwater lens causes seawater to displace the remaining freshwater, this is termed *seawater intrusion* [Fig. 14.19, Keller, 2011]
- see Florida examples (esp. Fig. 53-55)

Case Studies

Stream Ecosystem Health



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Figure 6: U.S. “wadable” stream ecosystem health by region [Fig. 14.18, Keller, 2011]. While pollution measures are chiefly declining, a more sensitive measure ecosystem health remains impaired, especially in the NE U.S.

Mercury Pollution

- some pollutants like *mercury* are increasing in abundance in U.S. waters [Fig. 11.9, Keller, 2000]
- *biomagnification* [Fig. 14.12, Keller, 2011] causes an increase in mercury content higher in the food chain, typically becoming highly abundant in fish and seafood
- worst human impact is on pre-natal development (USGS Factsheet or Minimata, Japan CAUTION: disturbing image)
- most coastal states and the Federal Government have issued fish-consumption advisories for pregnant women, based on high mercury contents (Fig. 7)

- see USGS Factsheet
- see Texas fish advisories

- 2006 studies indicate health benefit of fish oil outweighs mercury risk

- 2009 USGS study reveals mercury in *all game fish* examined in U.S. streams, 25% of those exceed EPA standards, 2/3 exceed healthy levels for fish-consuming wildlife (Fig. 8)

- EPA recently proposed new limits on mercury emissions

US Mercury Advisories

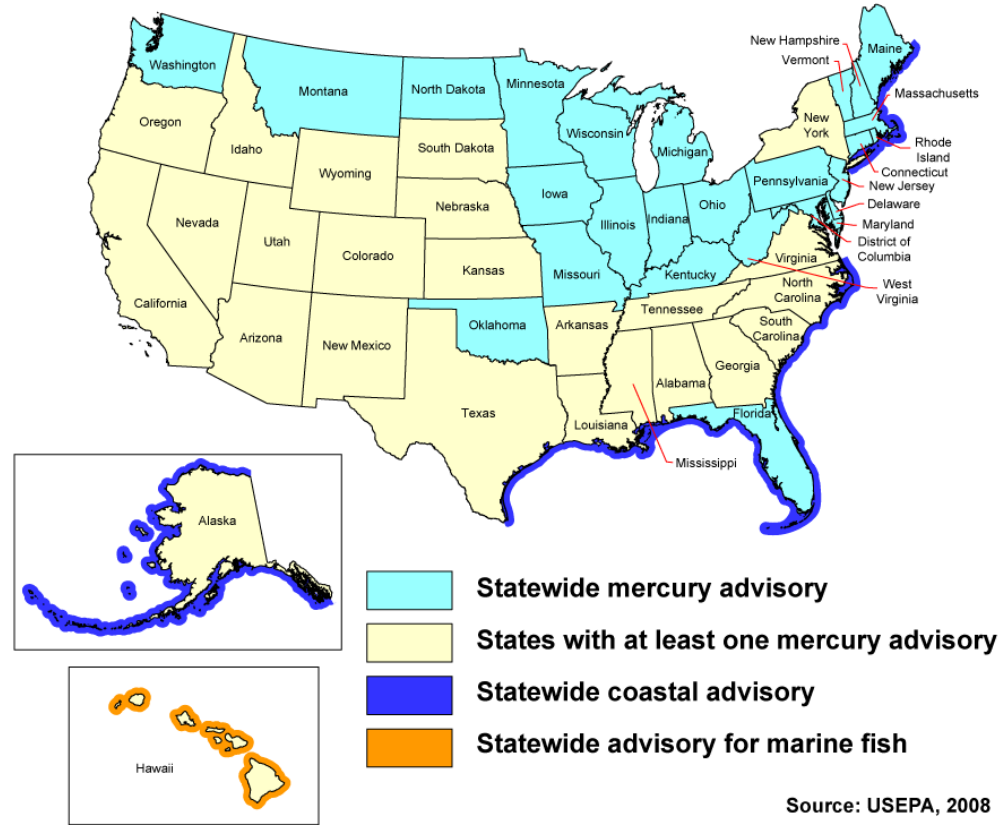


Figure 7: U.S. states and areas with fish-consumption advisories based on mercury content. **Every state** has at least one mercury fish consumption advisory. From USGS .

Mercury in US Game Fish

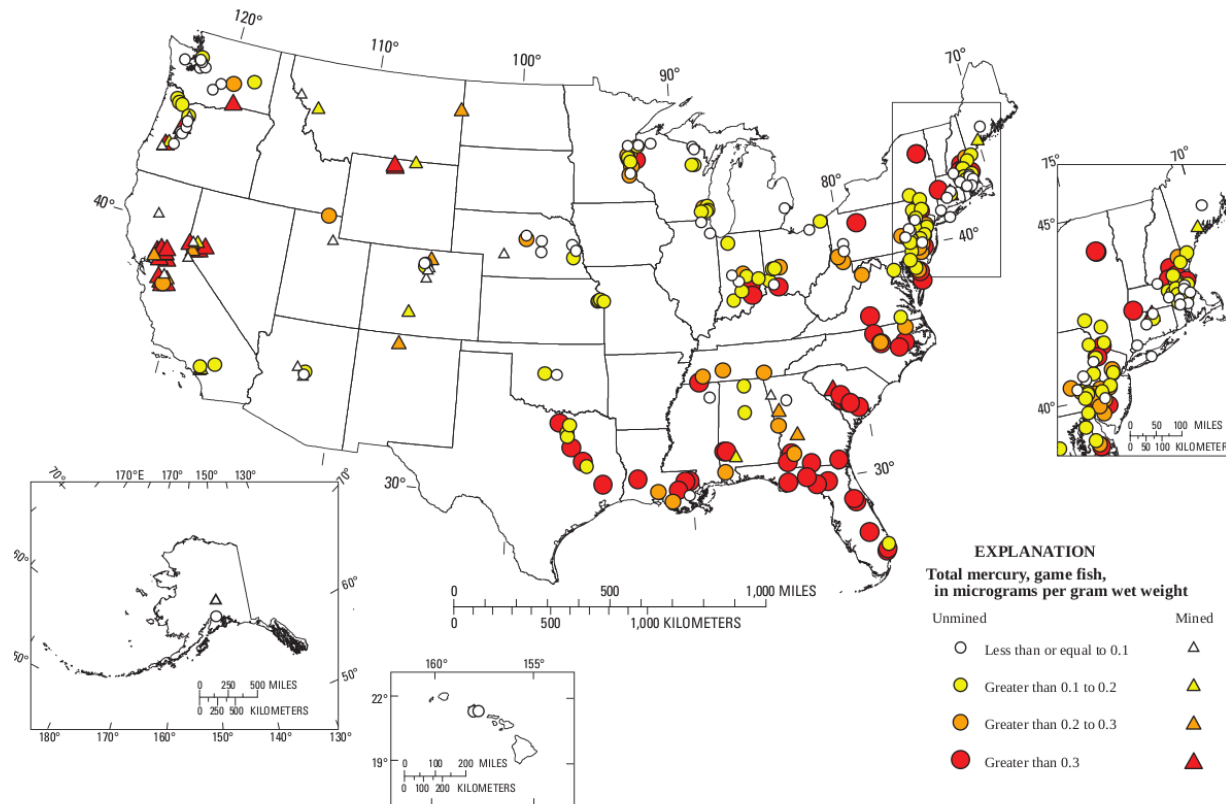


Figure 5. Spatial distribution of total mercury concentrations in game fish, 1998–2005.

Figure 8: Mercury content of game fish in the U.S., 1998-2005 [Scudder et al., 2009]. Elevated mercury found in all samples, 25% exceed EPA guidelines for humans, 75% at harmful levels for predator species.

Mercury Source

- recent studies demonstrate the bulk of mercury in surface water and oceans is deposited from the atmosphere, i.e. air pollution (Fig. 9)
- at least 30% of uncontrolled mercury emission sources in the U.S. are coal fired power plants
- Texas contains 5 of the 10 largest single emitters of mercury in the U.S.
- EPA's now-rescinded Clean Air Mercury rule proposed "cap and trade" to mercury, perhaps unwise for bioaccumulative contaminants

- mercury can be readily removed from power plant smoke emissions using existing technology

Mercury Ice Core

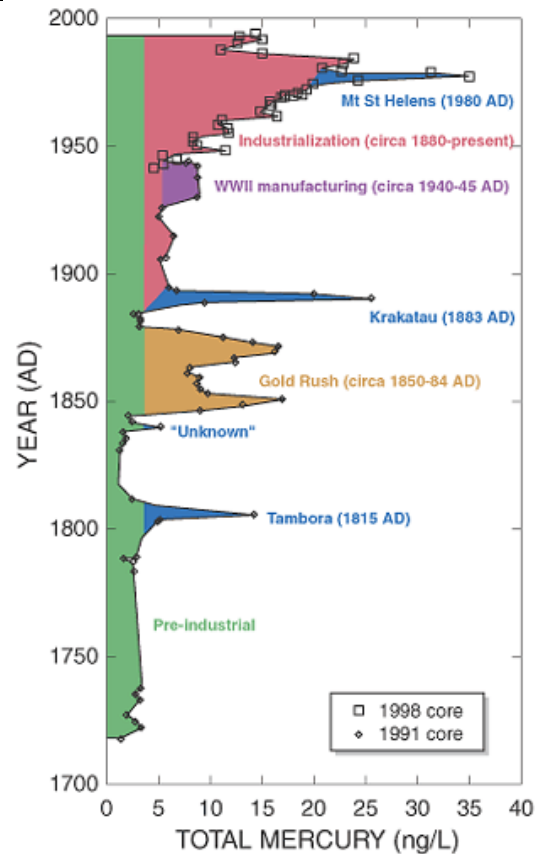


Figure 9: Anthropogenic contribution to aerosol mercury, based on ice cores taken from the Wind River Mountains, WY. After USGS factsheet .

Deposition of Mercury, U.S.

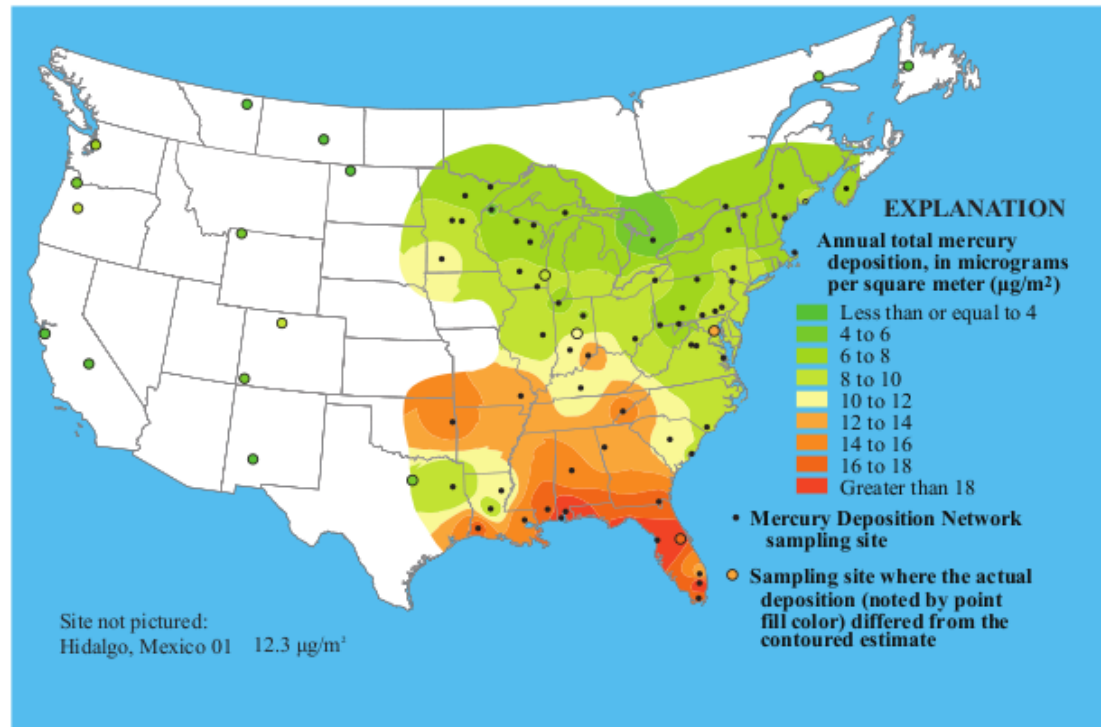


Figure 2a. Map showing location of Mercury Deposition Network sampling sites and contours of 2005 total annual mercury wet deposition. Map shows that wet deposition of mercury is greatest along the Gulf Coast and in Florida. (From National Atmospheric Deposition Program, 2007)

Figure 10: Wet (rain) deposition of mercury in the U.S. For unknown reasons more coal pollution in north-central U.S., but more mercury in south (see USGS factsheet).

Chesapeake Bay

- water quality had been degraded by high nutrient input and toxic metals
- large cleanup program was implemented in 1983, with the major deadline for controlling pollution (nutrient) input set for June 2000
- nutrient load continues to increase, fish, crustacean and shellfish populations have declined dramatically
- must study and remediate each local watershed
- see other references: National Geographic and USGS Project Summary

- EPA likely to sue over failure to meet pollution cutbacks
- 2011 study shows declining area of dead zones since 1980's

Hudson River

- was severely polluted by the 1960's, local efforts such as Pete Seeger's Clearwater Festival sparked a turnaround
- primary modern problem is industrial discharges of PCB's (ended in 1977) now stored in river sediments
- primary responsible party is General Electric
- two options, long debate
 - leave PCB's in place, limiting further exposure (EPA's choice in 1984)
 - remove PCB-contaminated bottom sediment, removing hazard completely, but increasing exposure during dredging

(EPA's choice in 2002 , see GE dredging project website)

- see also EPA Hudson River Superfund Site webpage
- waste is shipped to Andrews, TX for disposal in secure landfill
- sewage discharge destroyed a large oyster industry in the Hudson by the 1930's

Long Island, NY

- Long Island is steadily urbanizing, and has a combination of anthropogenic and natural contaminants threatening its groundwater
- aquifer recharge is primarily from the crest of the island [Fig. 13.2, Keller, 2011]
- nutrients (nitrate) from urban applications is generating a seaward-bound plume [Fig. 11.E, Keller, 2000]
- cities pump from deep aquifer, discharge to shallow, polluting it in the process

Water Treatment/Remediation

Surface Water Treatment

- wastewater treatment is the most extensive application of pollution reduction. It is done at two scales:
 - individual household: septic tank [Fig. 14.20a, Keller, 2011]
 - urban: wastewater treatment plant [Fig. 14.21, Keller, 2011]
- less contaminated or partially-treated water can be diverted for *reuse* in a process termed *wastewater renovation* [Fig. 13.16, Keller, 2008]
- such reuse is part of the Metroplex's future water plan, the first project (pg. 17) is landscape application at Cedar Crest Golf Course in Oak Cliff

- engineered wetlands can be used for small-scale wastewater treatment [Fig. 11.13, Keller, 2000]
- Dallas' Trinity River Project includes wetlands facility , partly for water quality improvement from wastewater treatment plant
- good overview at [Wikipedia sewage treatment summary](#)
- extensive reuse of Trinity River water means that [see [Trinity River Authority](#) and [Fono et al., 2006](#)]

“In dry weather, it is not at all uncommon for the base flow of the Trinity River to be *95 percent treated wastewater*. The Trinity River remains vulnerable and provides very little dilution. Because of these

considerations, wastewater treatment plant operators process wastewater to the most advanced treatment standards in the nation.”

Ground Water Treatment

Four main treatment technologies are used (e.g. online summary) [Tbl. 14.4, Keller, 2008]:

- *extraction wells* for *free product* and contaminated water
- *vapor extraction wells* (for volatile gases in vadose zone)
- *bioremediation*: addition or maintenance of bacteria that break down organic chemicals (Fig. 11) (AKA *natural attenuation* (see EPA)
- *Permeable treatment bed*: good for metals, often made of iron bits and Cr^{VI} cost analysis

Bioremediation

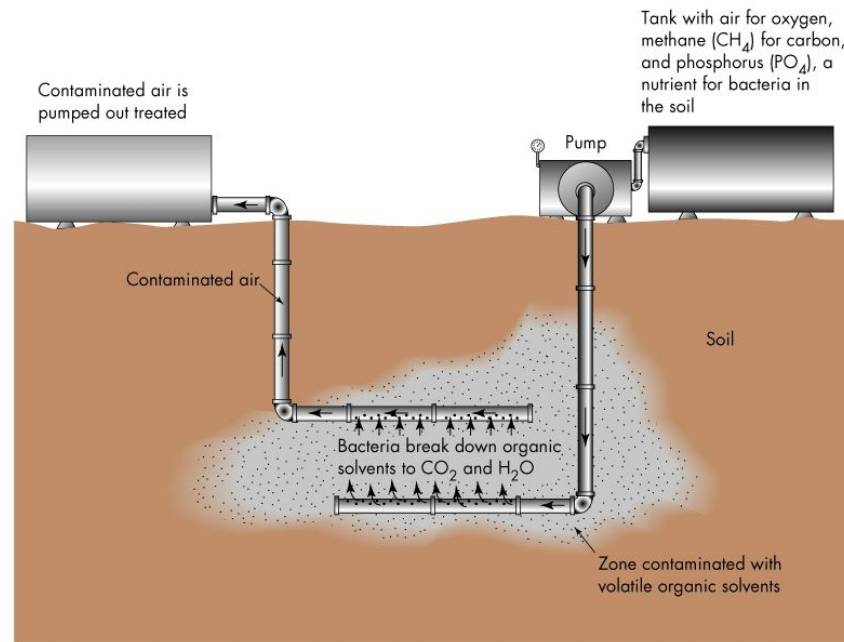


Figure 11: Bioremediation of a contaminated soil [Fig. 16.20, Keller, 2005]. Oxygen and nutrients are generally supplied to maintain a healthy natural or introduced bacterial population.

Purification in Developing Countries

- developing countries typically lack resources for thorough treatment of water
- lack of access to safe drinking water is a rapidly growing problem world-wide
- some low-technology approaches are available:
 - solar purification, using clear plastic bottles (e.g. see BBC Tanzania story). Sunshine used to heat water to higher than 50 C for several hours, killing most pathogens.
 - solar oxidation: add small amount of citric acid, follow same process as solar purification, see online study . Metals precipitate out as fine grit, and are filtered out with a cloth.

Local Issues

Richardson Utilities

- Richardson operates its water supply and treatment in concert with several neighboring cities (North Texas Municipal Water District)
- water supply mainly from Lake Lavon in conjunction with North Texas Municipal Water District
- note water reuse is growing in NTMWD (see Wilson Creek sewage treatment plant
- sewage is handled by drainage basin. UTD sewage moves parallel to Cottonwood Creek, eventually to be treated in Dallas by agreement with Richardson (Fig. 12)

DFW Wastewater Discharge

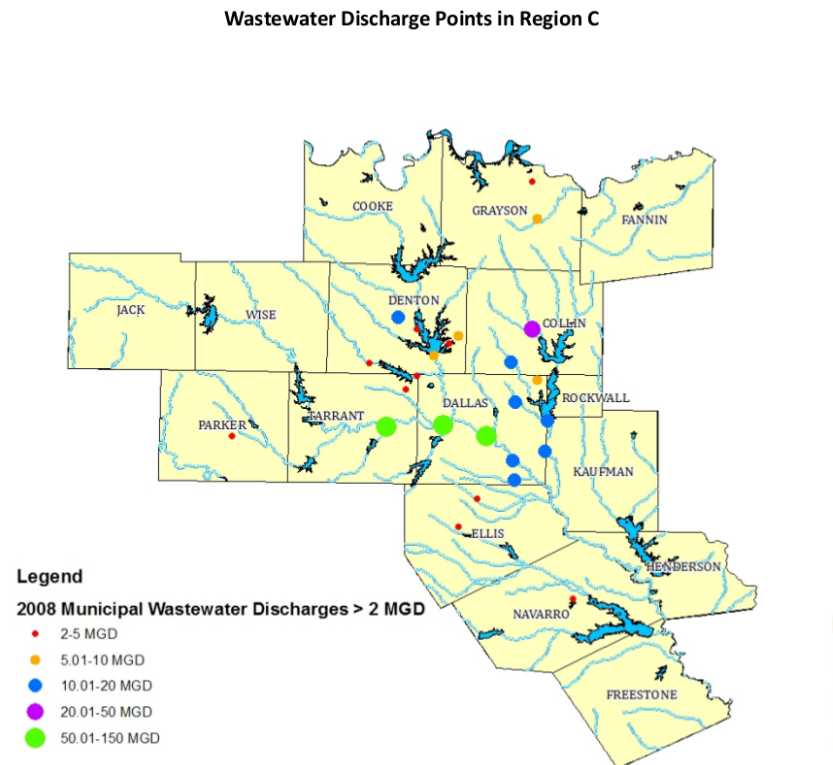


Figure 12: Wastewater discharge points in the Region C water planning area. From [Freese and Nichols, Inc., 2011, Fig. 1.18].

Brownfields Program

DALLAS, TX: American Airlines Center is Big Brownfields Victory for Big D

The home of the NBA's Dallas Mavericks and the NHL's Dallas Stars, the American Airlines Center is the centerpiece of the Victory Project, a 72-acre brownfield redevelopment that has become one of the country's most successful cleanup stories and has helped revitalize Dallas's central business district.

The Victory Development is located on a former industrial area with the centerpiece American Airlines Center located on a portion of an old electric power generating plant site that began operating in the late 1800s. Operations and facilities at the power generating plant included petroleum product storage and delivery facilities and cooling water reservoirs and



towers. Maintenance activities over the years resulted in petroleum hydrocarbon, solvent, metals, and asbestos impacted soil. Other environmental concerns included: (1) historic filling of the area with industrial and municipal solid waste, which resulted in metals and polynuclear aromatic hydrocarbon (PAH) impacted material; (2) leaking petroleum storage tank sites, which resulted in petroleum hydrocarbon affected soil and groundwater; (3) a grain elevator, which resulted in pesticide impacted construction debris; and (4) a

former railyard maintenance facility and turntable/switching area, which resulted in petroleum hydrocarbon impacted media.

Figure 13: American Airlines Center Brownfields development project. This EPA program limits liability for development of contaminated industrial lands, turning areas of urban blight (“brownfields”) into useful properties. Development is designed to limit exposure to remaining contaminants (e.g. parking lots seal the ground).

Other Resources

Useful Links

This is intended to be an ever-evolving list of useful links on the general topic of this note set.

- EPA GoogleEarth file showing Brownfields locations that might be good for renewable energy development (e.g. subsurface already trashed, but surface good for solar collectors, etc.)
- Endocrine-disruptors as contaminants. Controversial, since environmental exposure is very small (see dose-response notes)
- Lax EPA enforcement may threaten progress in cleaning up rivers

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