

Hazardous Wastes and the Superfund Act

Chapter 19 (part) – Manahan, 7th ed.

Definition

Hazardous wastes = substances that have been discarded or designated as waste and that pose a danger (Baird & Cann, p. 614)



= substances that may interact with other substances to be hazardous (Manahan, 7th ed., p. 527)

Q. How long ago was the first hazardous waste generated?

History of Hazardous Materials

Prehistoric times (*Ice Age*)

- ❖ Exposure to *carbon monoxide*
 - Inadequate venting of fires in caves

Ancient Greece

- ❖ *Asbestos* exposure leading to lung disease
 - Slaves wove asbestos fibers into cloth => increased durability


Roman Empire and *Lead Poisoning* (p. 591, 2nd ¶)

Middle Ages

- ❖ *Explosive* and *toxic chemical* exposures by the alchemists
=> debilitating injuries and illnesses

Famous Hazardous Waste Sites

Minamata Bay, JAPAN

- ❖ 1950s: Industrial wastes containing tons of *mercury* were poured into the Minamata bay
 - Mercury was converted into highly toxic *organomercury compounds* (biological process)
 - Worked their way up the food chain (bioaccumulation) 
 - Hundreds of people died from eating Hg-contaminated fish
 - Thousands developed severe mental and physical disorder



An image of an outwardly healthy mother bathing her fetal-poisoned 16 year old daughter, physically crippled since birth due to environmental industrial mercury poisoning in the local Minamata, Japan, water supply.



An aide mops the brow of Chisso's President Shimada during one of the grueling negotiating sessions for compensation.

<http://www.geocities.com/minoltaphotographyw/williamegenesmith.html>

Famous Hazardous Waste Sites (*Cont.*)

The Love Canal

- Niagara Falls, NY
- 1940s & 50s - Hooker Chemical (chemical and plastic industry) filled the canal with about 21,000 tons of **organic solvents**, **acids**, **pesticides** and their by-products
 - ❖ **Carcinogenic**
 - ❖ **Teratogenic** (creating birth defects)
- 1980 - More than 230 families relocated
 - ❖ Chemical leaks from corroded drums of hazardous waste contaminated the whole area

EPA Press Release: "U.S. Sues Hooker Chemical at Niagara Falls, New York" <http://www.epa.gov/history/topics/lovecanal/02.htm>

The Worst Environmental Disasters Of All Time (Thu, Oct 1, 2009)
Earth, Environment, Nuclear Power, Planet, Pollution

<http://saviamgreen.com/blog/2009/10/the-worst-environmental-disasters-of-all-time/>

Love Canal



In 1953, Hooker chemical sold a piece of land that was used as a chemical waste dump to the Niagara falls school district for the purpose of building a school on. Knowing full well of the risks, the school district bought the land for one dollar and agreed to release hooker of all liabilities from the contamination. With the soil disturbed by building, the entire property, along with residential neighborhoods around it become contaminated causing a plethora of health problems. The contamination at the love canal was the catalyst for the creation of the Comprehensive Environmental Response, Compensation, and Liability Act.

Chemicals soon started rising to the soil's surface, Gondek recalls. "We kids would go over [by the canal], and you would see a bubble form—oh, I would say about 9 to 12 inches in diameter," she says. Kids would quickly gather up stones to throw into the chemical-filled hole.



They didn't know it, but the bubbles formed when a metal drum of chemicals rusted through and broke underground. The soil above it would collapse into the drum and force chemicals to the surface; then the sides of the hole would close back up after a minute or two.

Black Goo Bubbles of chemicals would appear in the ground when chemical drums burst; shown is a sinkhole in 1978.

COURTESY OF ADELINE LEVINE AND UNIVERSITY ARCHIVES, THE UNIVERSITY AT BUFFALO, SUNY

Happy Birthday, Love Canal. C&EN News Nov. 17, 2008, available at <http://pubs.acs.org/cen/government/86/8646gov2.html>



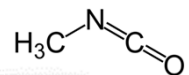
Source: C. Snyder, "The Extraordinary Chemistry of Ordinary Things," 4th ed. Wiley, 2003.

Famous Hazardous Waste Sites (*Cont.*)

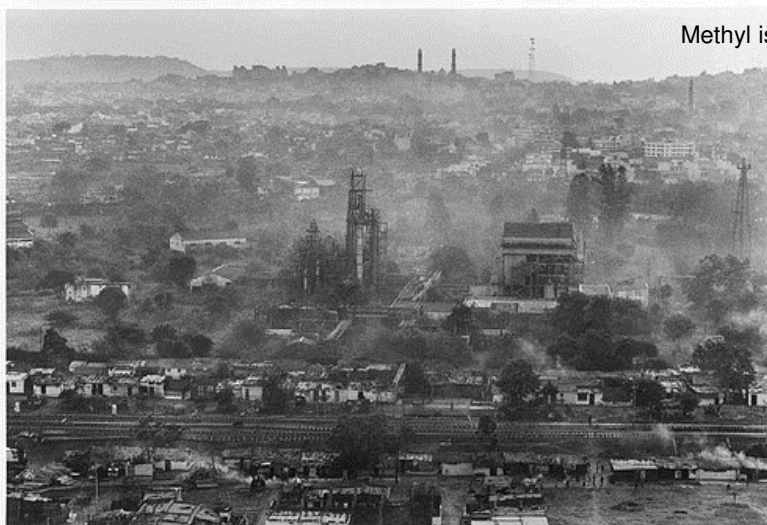
Bhopal, INDIA

- ❖ December 1984 = Industrial accident; Union Carbide* India Ltd.
- ❖ Explosion at a UCIL plant that manufactures *methyl isocyanate*
 - Used in manufacture of pesticide
 - A deadly compound: "Exposure to high concentrations could result in severe damage to your lungs that might be fatal." *ATSDR ToxFAQs*
- ❖ About 50,000 lbs of the compound was released in the air
 - **2000+ people died**
 - 200,000 injured
 - Death toll est. between **15,000 to 20,000**

* In 2001 Dow bought Union Carbide



Methyl isocyanate



Bhopal, India. Image available at <http://www.briancabral.com/BrianCabral/Global>

Dec. 3rd 1984

the worst ever
industrial disaster
happens in Bhopal

Just after midnight a cloud of toxic gas leaked from a Union Carbide pesticide factory in Bhopal, India, and spread over the city.

At least 8,000 people died within the first few days of the leak and, to date, a total of at least 25,000 have died as a result of the disaster.

The Sambhavana clinic, situated in the worst affected area of Bhopal, is the only centre offering free, rational treatment to those affected by the gas and water poisoning

[Click here to learn more](#)



3rd December 1984

Shortly after midnight poison gas leaked from a factory in Bhopal, India, owned by the Union Carbide Corporation. There was no warning, none of the plant's safety systems were working. In the city people were sleeping. They woke in darkness to the sound of screams with the gases burning their eyes, noses and mouths. They began retching and coughing up froth streaked with blood. Whole neighbourhoods fled in panic, some were trampled, others convulsed and fell dead. People lost control of their bowels and bladders as they ran. Within hours thousands of dead bodies lay in the streets.

Remember Bhopal. <http://studentorgs.utexas.edu/aidaustin/bhopal/>



Images available at <http://www.greenpeace.org/multimedia/?campaign%5fid=3991>



'I remember making three tiered graves. There was no option but to pile up one body on top of another. In those three to four days we must have buried more than 4,000 people' says Mohammad Aziz as he looks at the skeletons that have come out of the graves.

How do we prevent these from happening again?

U.S. Legislation

Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) of 1980 or the **Superfund Act**

- Federal program – goal is to clean up the nation's uncontrolled hazardous waste sites
 - Created to *eliminate the health and environmental threats* posed by hazardous waste
 - Superfund's major goals include: (p. 593)
 - ❖ **Locating**
 - ❖ **Investigating**
 - ❖ **Cleaning up of hz waste**
- └───┬───> Danger from waste site?
 └───> Danger to the environment?

Source: <http://www.epa.gov/superfund/sites/>

How Superfund Works - <http://www.epa.gov/superfund/about.htm>

Basic steps:

- 1) Assess sites,
- 2) Place sites on the [National Priorities List](#)^{*}, and
- 3) Establish and implement appropriate cleanup plans.

* Sites that warrant further investigation

As of 2009, the program has:

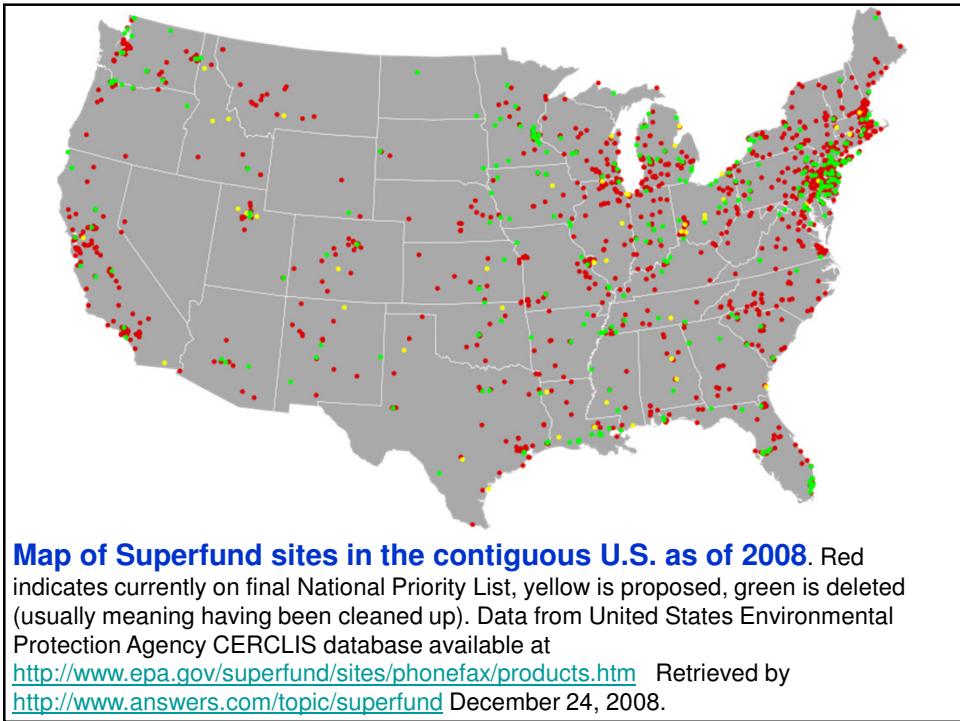
- Assessed 40,558 out of 44,359 sites
 - About 25 % of these sites are either still under assessment or are moved into the NPL

Today, the six New England states have **115** toxic and hazardous waste sites on the Superfund NPL. Of these, 35 are in the state of Massachusetts.

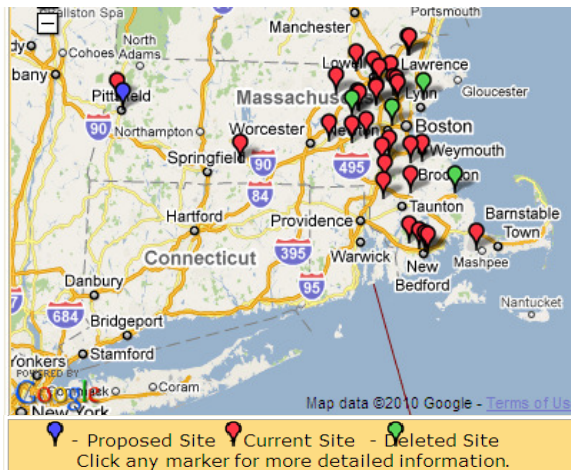
1 - 35 of 35 results for [State has Massachusetts AND Site Type has "Long Term/National Priorities List NPL"]. Results are sorted by site name.

Site Name	State	Site Type	City	C.D.	County
<input type="checkbox"/> ATLAS TACK CORP.	MA	NPL	Fairhaven	04	Bristol
<input type="checkbox"/> BAIRD & MCGUIRE	MA	NPL	Holbrook	09	Norfolk
<input type="checkbox"/> BLACKBURN AND UNION PRIVILEGES	MA	NPL	Walpole	09	Norfolk
<input type="checkbox"/> CANNON ENGINEERING CORPORATION (BRIDGEWATER)	MA	NPL	Bridgewater	09	Bristol, Plymouth
<input type="checkbox"/> CHARLES GEORGE RECLAMATION TRUST LANDFILL	MA	NPL	Tyngsborough	05	Middlesex
<input type="checkbox"/> FORT DEVENS	MA	NPL	Shirley, Ayer, Lancaster, Harvard	05	Middlesex, Worcester
<input type="checkbox"/> FORT DEVENS-SUDBURY TRAINING ANNEX	MA	NPL	Sudbury and Maynard and Hudson and Stow	05	Middlesex
<input type="checkbox"/> GROVELAND WELLS NO. 1 & 2 SITE	MA	NPL	Groveland	06	Essex
<input type="checkbox"/> HANSCOM FIELD/HANSCOM AIR FORCE BASE	MA	NPL	Bedford, and Concord and Lexington and Lincoln	06	Middlesex
<input type="checkbox"/> HATHEWAY & PATTERSON	MA	NPL	Mansfield	04	Bristol
<input type="checkbox"/> HAVERHILL MUNICIPAL LANDFILL	MA	NPL	Haverhill	06	Essex
<input type="checkbox"/> HOCOMONCO POND	MA	NPL	Westborough	03	Worcester
<input type="checkbox"/> INDUSTRI-PLEX	MA	NPL	North Woburn	07	Middlesex
<input type="checkbox"/> IRON HORSE PARK	MA	NPL	North Billerica	05	Middlesex
<input type="checkbox"/> MATERIALS TECHNOLOGY LABORATORY (USARMY)	MA	NPL	Watertown	07	Middlesex
<input type="checkbox"/> NATICK LABORATORY ARMY	MA	NPL	Natick	07	Middlesex

<input type="checkbox"/> NAVAL WEAPONS INDUSTRIAL RESERVE PLANT	MA	NPL	Bedford	06	Middlesex
<input type="checkbox"/> NEW BEDFORD SITE	MA	NPL	NEW BEDFORD and FAIRHAVEN and ACUSHNET and DARTMOUTH	04	Bristol
<input type="checkbox"/> NORWOOD PCBS	MA	NPL	Norwood	09	Norfolk
<input type="checkbox"/> NUCLEAR METALS	MA	NPL	Concord	05	Middlesex
<input type="checkbox"/> NYANZA CHEMICAL WASTE DUMP	MA	NPL	Ashland	03	Middlesex
<input type="checkbox"/> OLIN CHEMICAL	MA	NPL	Wilmington	05	Middlesex
<input type="checkbox"/> OTIS AIR NATIONAL GUARD BASE/CAMP EDWARDS	MA	NPL	Falmouth and Bourne and Sandwich and Mashpee	10	Barnstable
<input type="checkbox"/> PLYMOUTH HARBOR/CANNON ENGINEERING CORP.	MA	NPL	Plymouth	10	Plymouth
<input type="checkbox"/> PSC RESOURCES	MA	NPL	Palmer	02	Hampden
<input type="checkbox"/> RE-SOLVE, INC.	MA	NPL	North Dartmouth	03	Bristol
<input type="checkbox"/> ROSE DISPOSAL PIT	MA	NPL	Lanesborough	01	Berkshire
<input type="checkbox"/> SALEM ACRES	MA	NPL	Salem	06	Essex
<input type="checkbox"/> SHIPACK LANDFILL	MA	NPL	Attleboro and Norton	03	Bristol
<input type="checkbox"/> SILRESIM CHEMICAL CORP.	MA	NPL	Lowell	05	Middlesex
<input type="checkbox"/> SOUTH WEYMOUTH NAVAL AIR STATION	MA	NPL	Weymouth, Abington, Rockland	10	Norfolk, Plymouth
<input type="checkbox"/> SULLIVAN'S LEDGE	MA	NPL	New Bedford	04	Bristol
<input type="checkbox"/> SUTTON BROOK DISPOSAL AREA	MA	NPL	Tewksbury	05	Middlesex
<input type="checkbox"/> WELLS G & H	MA	NPL	Woburn	07	Middlesex
<input type="checkbox"/> W. R. GRACE & CO., INC. (ACTON PLANT)	MA	NPL	Acton, Concord	05	Middlesex



NPL Sites in Massachusetts



Total sites: 36
Currently on list: 31
Proposed: 1
Deleted (cleaned up): 4

About the data on this page: As a public service, the Center for Public Integrity created this state page reflecting Environmental Protection Agency databases that detail the location, status and other details regarding each Superfund site as of March 2007. This information has not been modified in any way. Any misspellings or errors already existed in the government database. <http://projects.publicintegrity.org/superfund/>

Sources and Generators of Waste

Sources and Generators of Waste

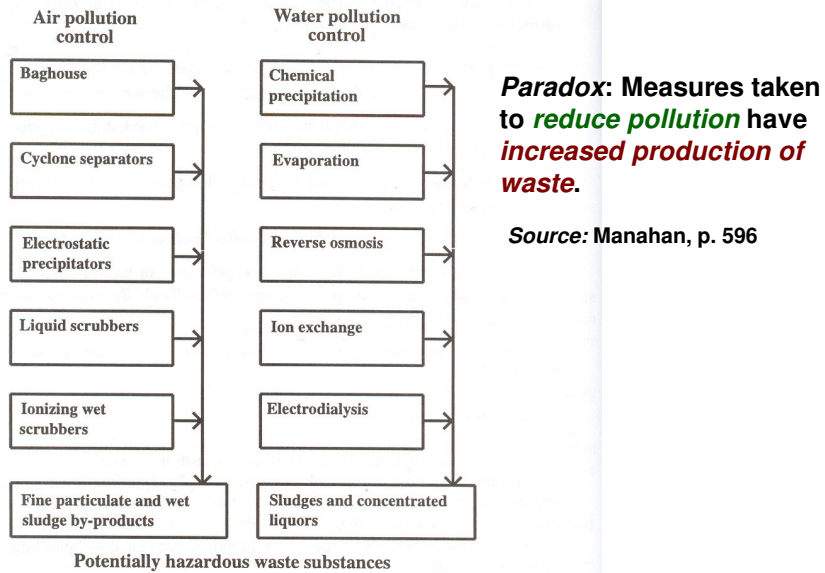
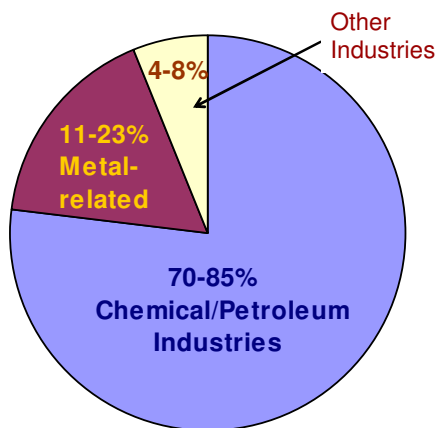


Figure 19.1. Potential contributions of air and water pollution control measures to hazardous wastes production.

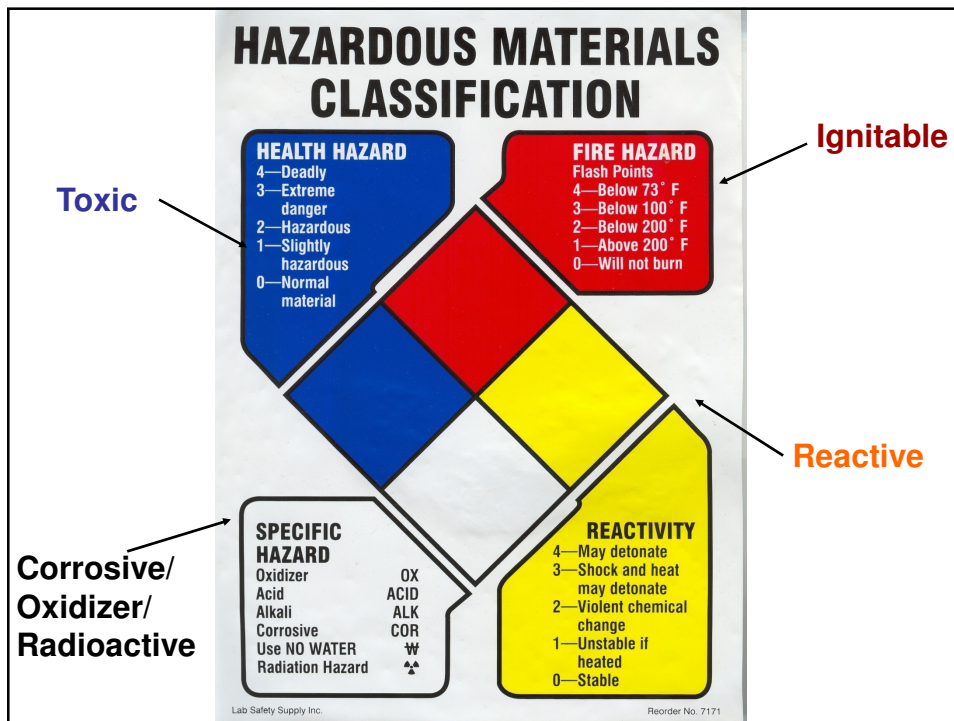
Generators of Hazardous Waste, Estimate in %



Classification of Hazardous Waste

- **Ignitable** = burns readily and easily
- **Corrosive** = acidic or basic substances that easily corrode other materials
- **Reactive** = can undergo violent reactions
- **Toxic** = threatens health when it enters the body
- **Radioactive** = releases radiation

Sources: Manahan, pp. 594-; Baird, pp. 506-515



Classification of Hz Waste – *Cont.*

Ignitable Waste - Examples

- ❖ **Flammable liquid** = lower ignition temp than combustible liquids
Ex. Diethyl ether, acetone, pentane
- ❖ **Combustible liquid**
Ex. Methylene chloride
- ❖ **Explosive dust**
Ex. Metal dust, such as that of Mg, Al
- ❖ **Oxidizers** => many are O-containing (Table 19.2)

Table 19.2. Examples of Some Oxidizers

Name	Formula	State of matter
Ammonium nitrate	NH_4NO_3	Solid
Ammonium perchlorate	NH_4ClO_4	Solid
Bromine	Br_2	Liquid
Chlorine	Cl_2	Gas (stored as liquid)
Fluorine	F_2	Gas
Hydrogen peroxide	H_2O_2	Solution in water
Nitric acid	HNO_3	Concentrated solution
Nitrous oxide	N_2O	Gas (stored as liquid)
Ozone	O_3	Gas
Perchloric acid	HClO_4	Concentrated solution
Potassium permanganate	KMnO_4	Solid
Sodium dichromate	$\text{Na}_2\text{Cr}_2\text{O}_7$	Solid

Mostly:

- ❖ **Nitrates**
- ❖ **Elemental form of the halogens**
- ❖ **Perchlorates**
- ❖ **Permanganate and dichromate salts**

Classification of Hz Waste – *Cont.*

Corrosive Substances

❖ Cause deterioration of materials that they come in contact with

❖ Include:

➤ **Strong acids** Ex. HCl, HNO₃, H₂SO₄, HF

➤ **Strong bases** Ex. NaOH and KOH

➤ **Dehydrating agent** = removes water from some compounds; exothermic

Ex. Concentrated H₂SO₄

↙ Leaves a charred mass upon contact with carbohydrates, like sugar

❖ More examples on Table 19.4, p. 604

Table 19.4. Examples of Some Corrosive Substances

Name and formula	Properties and effects
Nitric acid, HNO ₃ reacts	Strong acid and strong oxidizer, corrodes metal, with protein in tissue to form yellow xanthoproteic acid, lesions are slow to heal
Hydrochloric acid, HCl vapor,	Strong acid, corrodes metals, gives off HCl gas which can damage respiratory tract tissue
Hydrofluoric acid, HF	Corrodes metals, dissolves glass, causes particularly bad burns to flesh
Alkali metal hydroxides, NaOH and KOH	Strong bases, corrode zinc, lead, and aluminum, substances that dissolve tissue and cause severe burns
Hydrogen peroxide, H ₂ O ₂	Oxidizer, all but very dilute solutions cause severe burns
Interhalogen compounds such as ClF, BrF ₃	Powerful corrosive irritants that acidify, oxidize, and dehydrate tissue
Halogen oxides such as OF ₂ , Cl ₂ O, Cl ₂ O ₇	Powerful corrosive irritants that acidify, oxidize, and dehydrate tissue
Elemental fluorine, chlorine, bromine (F ₂ , Cl ₂ , Br ₂ ,)	Very corrosive to mucous membranes and moist tissue, strong irritants

Classification of Hz Waste – *Cont.*

Reactive Substances - *Examples*

- ❖ Undergo rapid or violent reactions under certain conditions
Ex. Trinitrotoluene (TNT) and nitroglycerin
- ❖ Reacts with water to form explosive mixtures
Ex. Alkali metals like Na and K
- ❖ Reacts with water, acid or base to form toxic vapors

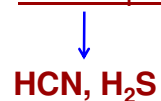


Table 19.3. Examples of Reactive Compounds and Structures

Name	Structure or formula	
<i>Organic</i>		
Allenes	C=C=C	} Unstable C-C multiple bonds
Dienes	C=C-C=C	
Azo compounds	C-N=N-C	} Unstable N-N double bond
Triazenes	C-N=N-N	
Hydroperoxides	R-OOH	} Peroxides
Peroxides	R-OO-R'	
Alkyl nitrates	R-O-NO ₂	
Nitro compounds	R-NO ₂	
<i>Inorganic</i>		
Nitrous oxide	N ₂ O	
Nitrogen halides	NCl ₃ , NI ₃	
Interhalogen compounds	BrCl	
Halogen oxides	ClO ₂	
Halogen azides	ClN ₃	
Hypohalites	NaClO	

Classification of Hz Waste – *Cont.*

Toxic substances

Those of main concern are:

- ❖ Heavy metals – such as Pb, As, Hg
- ❖ Organochlorine pesticides – such as DDT
- ❖ Halogenated organic solvents – such as CHCl_3 , CH_2Cl_2
- ❖ Polychlorinated biphenyls, PCBs

Classification of Hz Waste – *Cont.*

Radioactive waste

Examples:

- ❖ **Spent fuel** from nuclear power plants
 - Contains radioactive uranium or plutonium and their radioactive decay products
(= **high level waste**)

- ❖ **Medical waste** with low doses of radiation (= **low level waste**)

Environmental Chemistry of Hazardous Waste

Definition:

Environmental chemistry is the study of the:

- ❖ sources,
- ❖ reactions,
- ❖ transport,
- ❖ effects, and
- ❖ fates

of chemical species in the environment

Environmental Chemistry of Hazardous Waste, *Cont.*

Figure 19.3, p. 607. Interactions of hazardous wastes in the environment

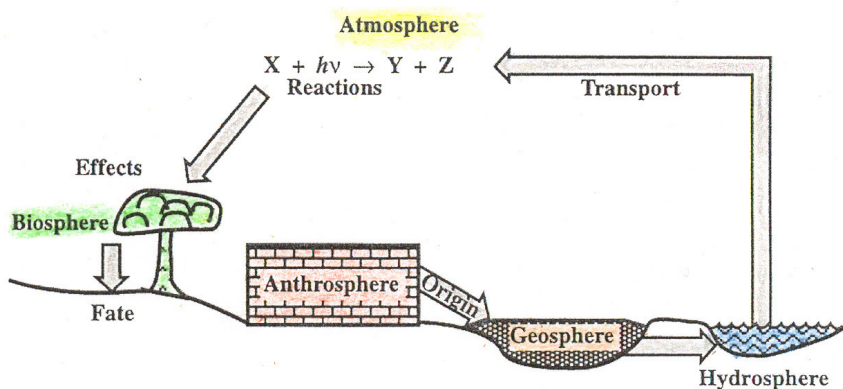


Figure 19.3. Scheme of interactions of hazardous wastes in the environment.

Hazardous Waste in the Geosphere

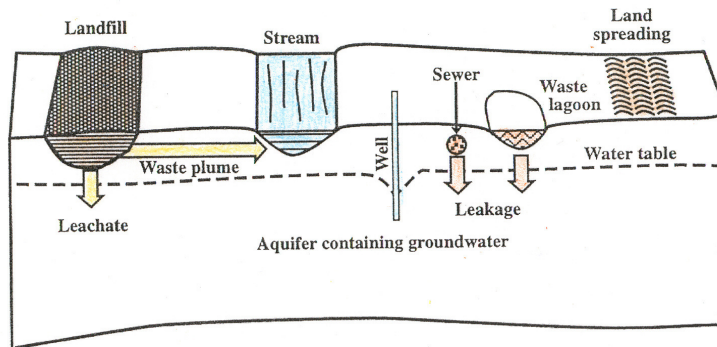
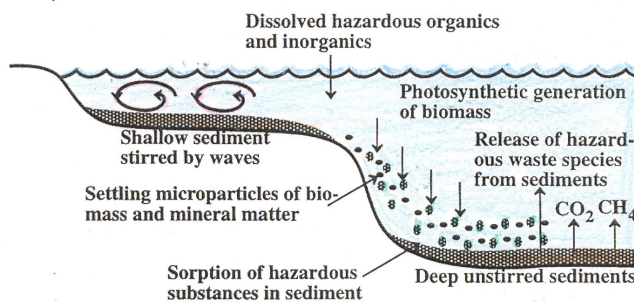


Figure 19.4. Sources and movement of hazardous wastes in the geosphere.

Means of entry into the groundwater: (Source of hz. waste is underlined)

- ❖ *Leaching* from landfills
- ❖ *Leaks* from sewers and pipelines
- ❖ *Leaks* or *drainage* from waste sites

Hazardous Waste in the Hydrosphere



Important role of sediment:

Figure 19.5. Aspects of hazardous wastes in surface water in the hydrosphere. The deep unstirred sediments are anaerobic and the site of hydrolysis reactions and reductive processes that may act on hazardous waste constituents sorbed to the sediment.

Accumulation or **release** of hz. waste

Means of entry into the hydrosphere: (Source of hz. waste is underlined)

- ❖ *Leaching* from waste sites
- ❖ *Runoff* from soil
- ❖ *Seepage* from sewer lines
- ❖ *Drainage* from waste ponds
- ❖ *Deliberate release* into waterways

Hazardous Waste in the Atmosphere

Mode of entry into the atmosphere: (Source of hz. waste is underlined>)

- ❖ *Evaporation* from waste sites
- ❖ *Direct release* (Ex. From smoke stacks, vehicles, etc.)
- ❖ *Wind erosion*

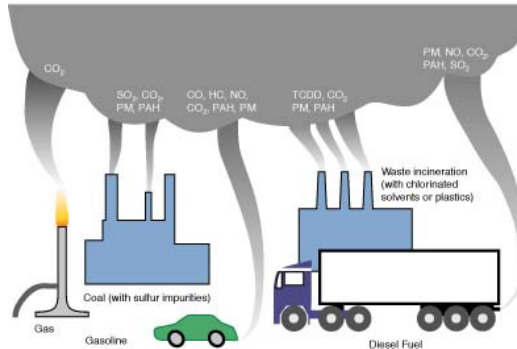
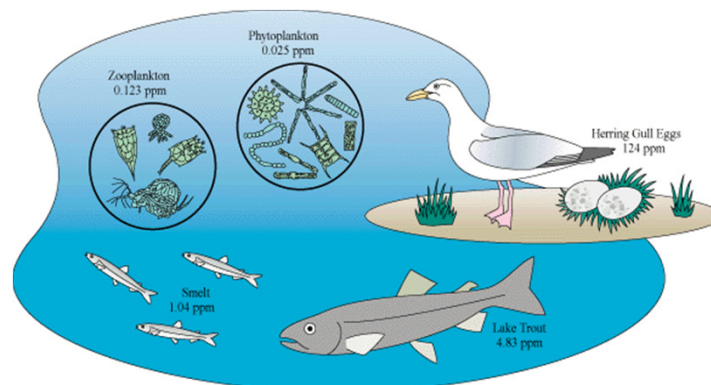


Image available at <http://www.envimed.com/emb03.shtml>

Hazardous Waste in the Biosphere

Bioaccumulation = concentration of waste in tissues of living organisms



Persistent organic chemicals such as PCBs bioaccumulate. This diagram shows the degree of concentration in each level of the Great Lakes aquatic food chain for PCBs (in parts per million, ppm). The highest levels are reached in the eggs of fish-eating birds such as herring gulls.

Image available at <http://www.concernedcitizens.homestead.com/osf.html>

Hazardous Waste in the Biosphere, Cont.

Biodegradation = breaking down of waste into simpler molecules/units by biological processes

Usually by microorganisms

- ❖ Bacteria
- ❖ Fungi
- ❖ Protozoa



<http://www.epa.gov/history/photos/p10.htm>



http://www.epa.gov/superfund/programs/er/resource/d1_22.htm