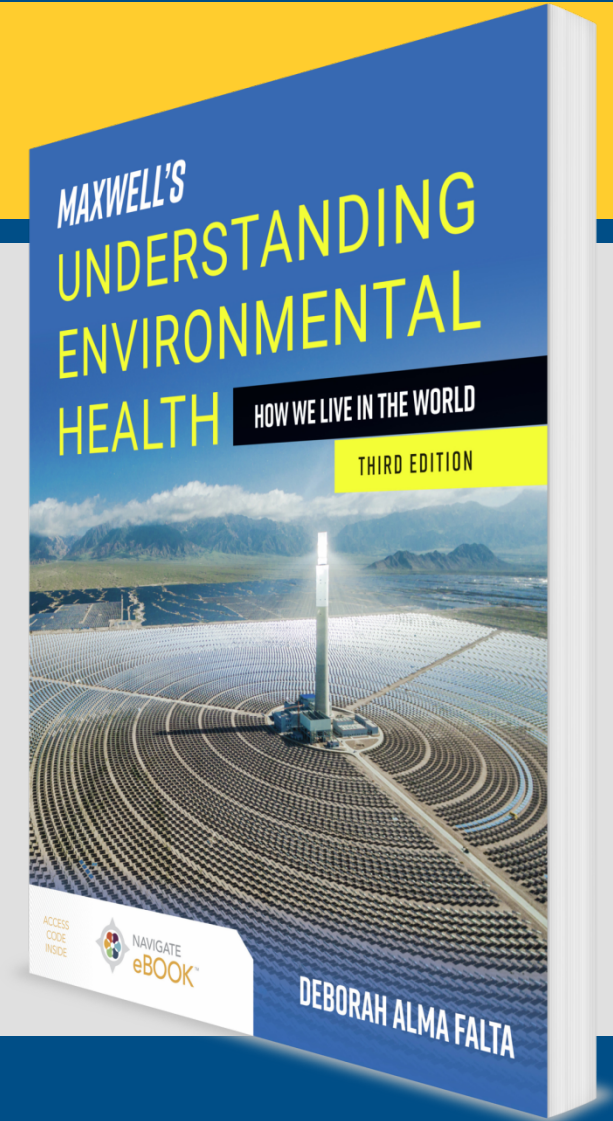


## CHAPTER 6

# Producing Manufactured Goods



# Introduction

- Social and economic changes in U.S.
  - Expectations and realities
    - “Use it up, wear it out, make it do”: thrift as a necessity and a virtue
    - Became “the good life”: house, car, washing machine, TV
    - Became “lifestyles”: luxuries as necessities
  - Changes in industry and pollution lead to
    - Visible air pollution
    - Hazardous wastes



**FIGURE 6.1** Polluted air blankets a U.S. city in 1946.

Courtesy of CDC Public Health Image Library. ID# 8998. Content provider CDC/Roy Perry. Available at: <http://phil.cdc.gov/phil/home.asp>. Accessed October 15, 2012.



**FIGURE 6.2** Workers wear protective gear as they handle hazardous wastes.

Courtesy of CDC Public Health Image Library. ID# 1530. Content provider: CDC. Available at: <http://phil.cdc.gov/phil/home.asp>. Accessed October 15, 2012.

## 6.1 Synthetic Organic Chemicals

6.2 Toxic Metals

6.3 Hazards in the Workplace

6.4 Management of Hazardous Products and Byproducts from Manufacturing

## **Organic Solvents**

*Phthalate Plasticizers and Bisphenol A*

*Persistent Toxic Substances*

*Ozone-Depleting Chemicals*

# Organic Solvents (1 of 2)

- Solvents: chemicals that dissolve other substances
  - Cleaning; synthesizing chemicals
    - Petroleum refineries
    - Chemical industry
    - Degreasing metals in electronics industries
    - Dying and dry cleaning textiles
  - Common groundwater contaminants

# Organic solvents

- Health effects<sup>4-6</sup>
  - Most affect central nervous system
  - Many damage liver, kidney
  - Cancer
    - Benzene: Group 1 (leukemia)
    - TCE, PCE: Group 2A
- Some widely used solvents (next slide)

**Table 6.1** Some Widely Used Organic Solvents

Nonchlorinated Solvents	Chlorinated Solvents
Benzene	Trichloroethylene (TCE)
Toluene	Tetrachloroethylene (PCE)
Ethylbenzene	1,1,1-Trichloroethane (TCA)
Xylene	



*Organic Solvents*

***Phthalate Plasticizers and Bisphenol A***

*Persistent Toxic Substances*

*Ozone-Depleting Chemicals*

# Phthalate Plasticizers and Bisphenol A

- Phthalate plasticizers: chemicals used to make plastics *plastic*
- Bisphenol A used in production to *stiffen*
- Both present in many plastic products
  - As semivolatile compounds, they slowly move from the plastic product into the air or liquid, if carbonated
- The phthalate family
  - DEHP: polyvinyl chloride (PVC) plastic
  - DINP: plastic toys
  - DBP, DEP, DMP: spreadable/sprayable products
- Indoor sampling and surveillance biomonitoring shows widespread exposure in U.S. population, but declining since peak in late 1990s<sup>24</sup>

# Health Effects of Phthalate Plasticizers and Bisphenol A

- Endocrine disruptors with xenoestrogenic properties
  - Developmental effects in male lab animals and male infants (hypospadias, reduced anogenital distance)
- Emerging evidence of link to obesity in lab animals and people
  - Term: obesogen



**FIGURE 6.4** Toxic BPA found in plastic bottles.

*Organic Solvents*

*Phthalate Plasticizers and Bisphenol A*

***Persistent Toxic Substances***

*Ozone-Depleting Chemicals*

# Persistent Toxic Substances (1 of 3)

- Opposite end of physical-chemical spectrum from volatile solvents
- All are halogenated (Cl, F, Br, I)
- PCBs, dioxins, and furans
  - PCBs: family of hi-MW manmade compounds
  - Chemically stable, nonflammable; used as insulating fluids in electrical equipment
  - Entered environment as industrial wastes
    - Primary contaminant of concern at NY and SC Superfund sites
  - Manufacture of PCBs created dioxins, furans as byproducts
  - All are lipophilic and persistent

# Persistent Toxic Substances (2 of 3)

- Dioxins also byproducts of other chemical processes
  - Production of herbicide 2,4,5-T (part of Agent Orange)
  - Pulp and paper industry (chlorine bleach)
  - Times Beach, MO from use of waste oils to control dust
- Acute exposure leads to chloracne
  - Seveso, Italy
  - Victor Yushchenko
- Dioxins detectable at low levels in everyone<sup>29</sup>
- Wide range of health effects in test animals
- Epidemiologic evidence suggests effects on neurologic development and cancer mortality<sup>39</sup>
- Cancer: PCBs Group 2A, dioxin Group 1<sup>5</sup>

# Persistent Toxic Substances (3 of 3)

- Polybrominated diphenyl ethers (PBDEs)
  - Used as flame retardants in many products
    - Penta-BDEs: in fabrics, foams
    - Octa- and deca-BDEs: in plastics
  - Not chemically bound to plastics or textiles, and accumulate in dust and sediments
  - Measured in wildlife and in humans
  - Most likely health effect: thyroid disruption<sup>41, 47</sup>

# Perhaps Most Persistent of All!

- Perfluorochemicals, PFCs
  - Process chemicals in production of water- and stain-resistant coatings
    - Scotchgard
    - Gore-Tex
    - Teflon
  - Perfluorooctanoic acid (PFOA) and perfluorooctane sulfonate (PFAS) are primary PFCs.
  - Released in industrial wastes
    - Widespread, do not biodegrade, bioaccumulate and biomagnify



# The C8 Science Panel on PFCs

- Industrial PFC contamination was the subject of the movie *Dark Waters*, released in 2019
- Class-action lawsuit settlement required the formation of the C8 Science Panel (C8 was Dupont's name for PFOA)
- Determined probability of a link between exposure to C8 to diagnosed high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension<sup>1</sup>

*Organic Solvents*

*Phthalate Plasticizers and Bisphenol A*

*Persistent Toxic Substances*

***Ozone-Depleting Chemicals***

# Ozone-Depleting Chemicals (1 of 2)

- Major cause: chlorofluorocarbons (CFCs)
  - Refrigerants, aerosol propellants, blowing agents
- Seemed ideal: nontoxic, not flammable or corrosive, chemically stable
- But due to stability, they reach stratosphere, where complex reactions with O, O<sub>2</sub>, and O<sub>3</sub> result in net loss of ozone <sup>59</sup>

# Ozone-Depleting Chemicals (2 of 2)

- Stratospheric ozone depletion results in
  - More UV exposure at earth's surface, especially UV-A and UV-B
  - Increased risk of skin cancer
- Ozone concentrations hit low in mid-1990s; little change since then<sup>59</sup>
- Recovery anticipated by mid-21<sup>st</sup> century due to controls of Montreal Protocol
  - International agreement to reduce production and consumption of specific chemicals with ozone-depleting potential

# Chemicals and Metals that Pose Serious Public Health Concerns

**Table 6.2** Leading Chemicals and Metals on the ATSDR's 2019 Substance Priority List

2019 Rank	Substance Name
1	Arsenic
2	Lead
3	Mercury
4	Vinyl Chloride
5	Polychlorinated Biphenyls (PCBs)
6	Benzene
7	Cadmium
8-10, 15	Polycyclic Aromatic Hydrocarbons (PAHs)*
11	Chloroform

**Table 6.2** Leading Chemicals and Metals on the ATSDR's 2019 Substance Priority List

2019 Rank	Substance Name
12	Aroclor 1260
13	DDT, P,P'-
14	Aroclor 1254
16	Trichloroethylene (TCE)
17	Chromium, Hexavalent
18	Dieldrin
19	Phosphorus, White
20	Hexachlorobutadiene

\*Polycyclic Aromatic Hydrocarbons are discussed later in the context of fossil fuel combustion.  
Data from Agency for Toxic Substances and Disease Registry. (2019). The ATSDR 2019 Substance Priority List. Retrieved from: <https://www.atsdr.cdc.gov/spl/index.html#2019spl>

6.1 Synthetic Organic Chemicals

**6.2 Toxic Metals**

6.3 Hazards in the Workplace

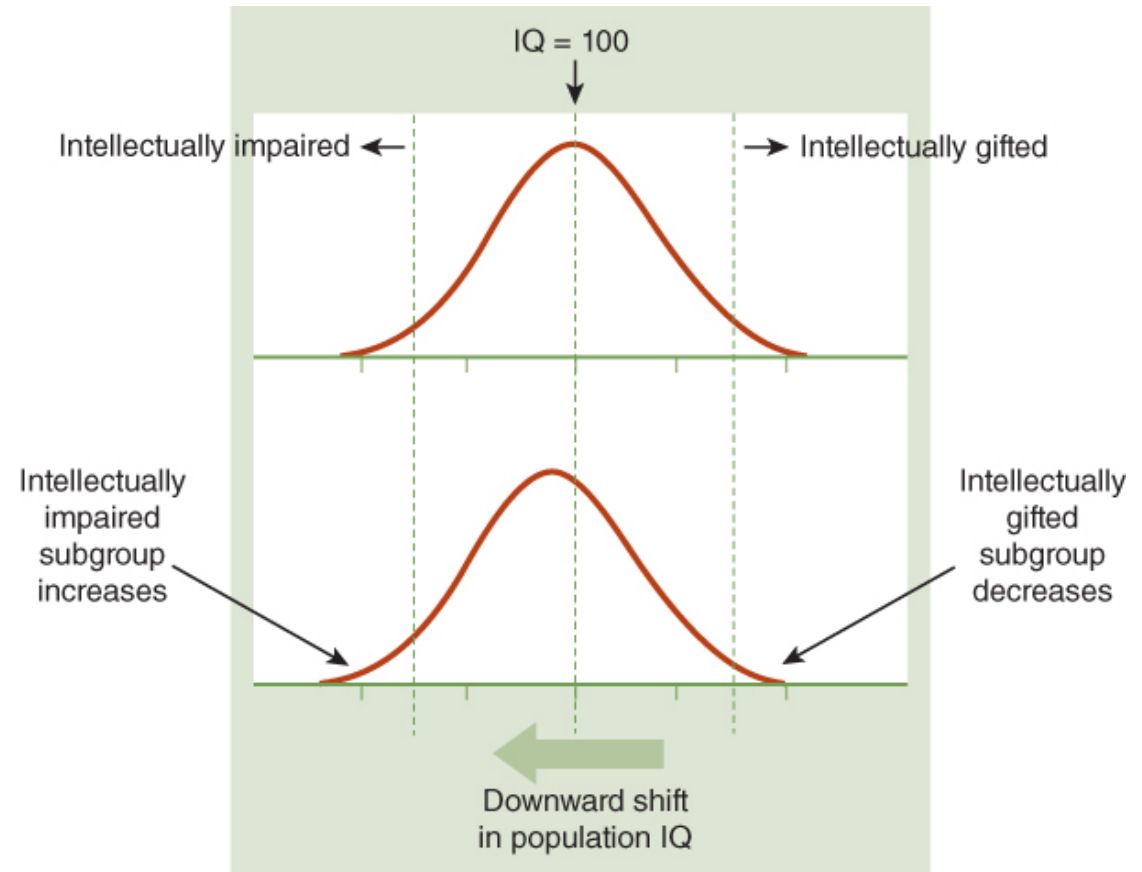
6.4 Management of Hazardous Products and Byproducts from  
Manufacturing

# Exposure to Lead (Pb)

- Used in gasoline and paints
- Aging lead pipes still used to deliver drinking water
  - Flint, MI water crisis
- Occupational exposures occur from smelting and demolition activities
- Recreational exposures from crafting stain glass and hunting/fishing

# Health Effects of Lead

- Neurotoxic heavy metal
  - Children particularly vulnerable
- CNS effects: memory, attention, IQ, behavioral problems
- Peripheral effects: “wrist drop”
- Renal toxicity, high blood pressure, miscarriage/stillbirth



**FIGURE 6.5** Decrease in intellectually gifted subgroup, and increase in intellectually impaired subgroup, with a small downward shift in population IQ.

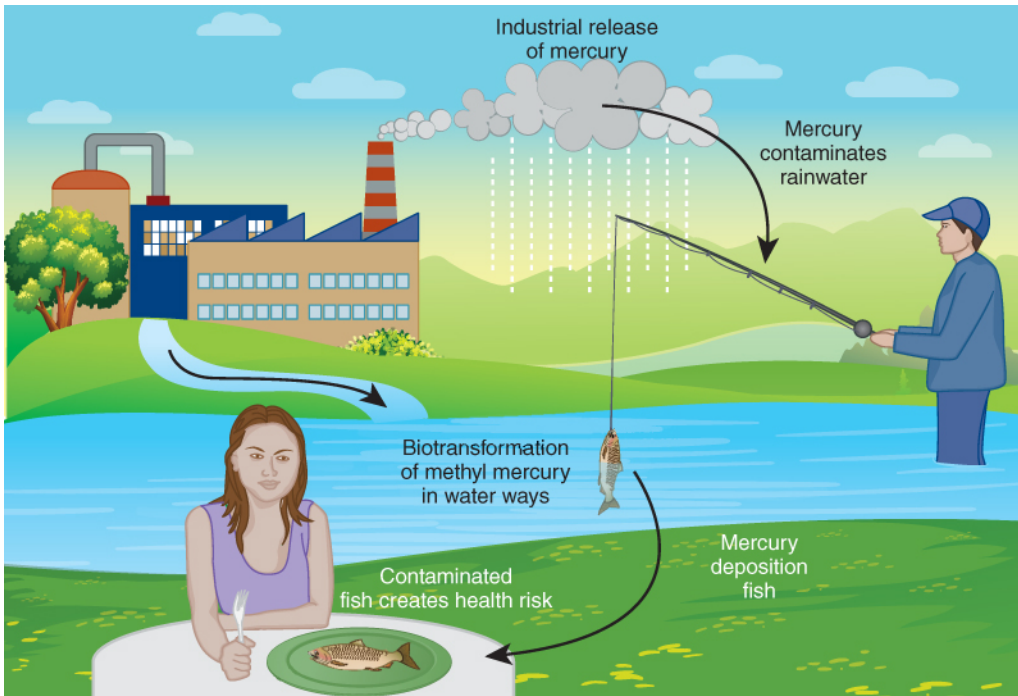
Reproduced from Gilbert SG, Weiss B. A rationale for lowering the blood lead action level from 10 to 2  $\mu\text{g}/\text{dL}$ . *NeuroToxicology*. 2006;27(5):693-701; Figure 3, with permission from Elsevier.



# Mercury (Hg)

## Exposure

- Elemental Hg biotransformed to methylmercury
- Primary exposure from fish



## Health Effects

- Strongly neurotoxic
- Causes mental retardation, cerebral palsy, deafness, blindness, motor impairments
- Minamata Bay, Japan
- Madhatter's disease includes excitability, delirium, and hallucinations
- Correlations suggested with PFAS<sup>79</sup>

**FIGURE 6.7** Methylmercury exposure.

Courtesy of CDC public Health Image Library. ID# 9527. Content providers CDC/Barbara Jenkins. Available at: <http://phil.cdc.gov/phil/home.asp>. Accessed October 15, 2012.

# Arsenic Exposure and Health Effects

- Widespread in earth's crust; groundwater contaminant
  - Bangladesh arsenic poisonings
- Copper smelters, tanneries
- Group 1 carcinogen; neurotoxic effects

# Overview of Toxic Metals\*

- Cadmium
  - Mining and smelting (lead, zinc); metal plating
  - Chronic obstructive pulmonary disease, chronic kidney disease; itai-itai
  - Group 1 carcinogen: lung cancer
- Chromium-VI
  - Chrome plating, leather tanning
  - Group 1 carcinogen: lung cancer
- Beryllium
  - Not a common metal
  - Strong, lightweight; used in high-tech industries (aircraft, space)
  - Chronic beryllium disease: debilitating lung disease; scarring, impaired breathing
  - Group 1 carcinogen: lung cancer

# Nanoscale Materials

- Nanoparticles: < 100 nm in diameter
  - Same size as ultrafine particulates; materials have different properties on nanoscale
  - Rapidly expanding technology for medicine, industry, consumer products
  - Health effects unclear; concern due to known effects of ultrafine particulates<sup>80</sup>
  - Nanotubes, like asbestos fibers, can cause toxicity because of shape.<sup>82</sup>

6.1 Synthetic Organic Chemicals

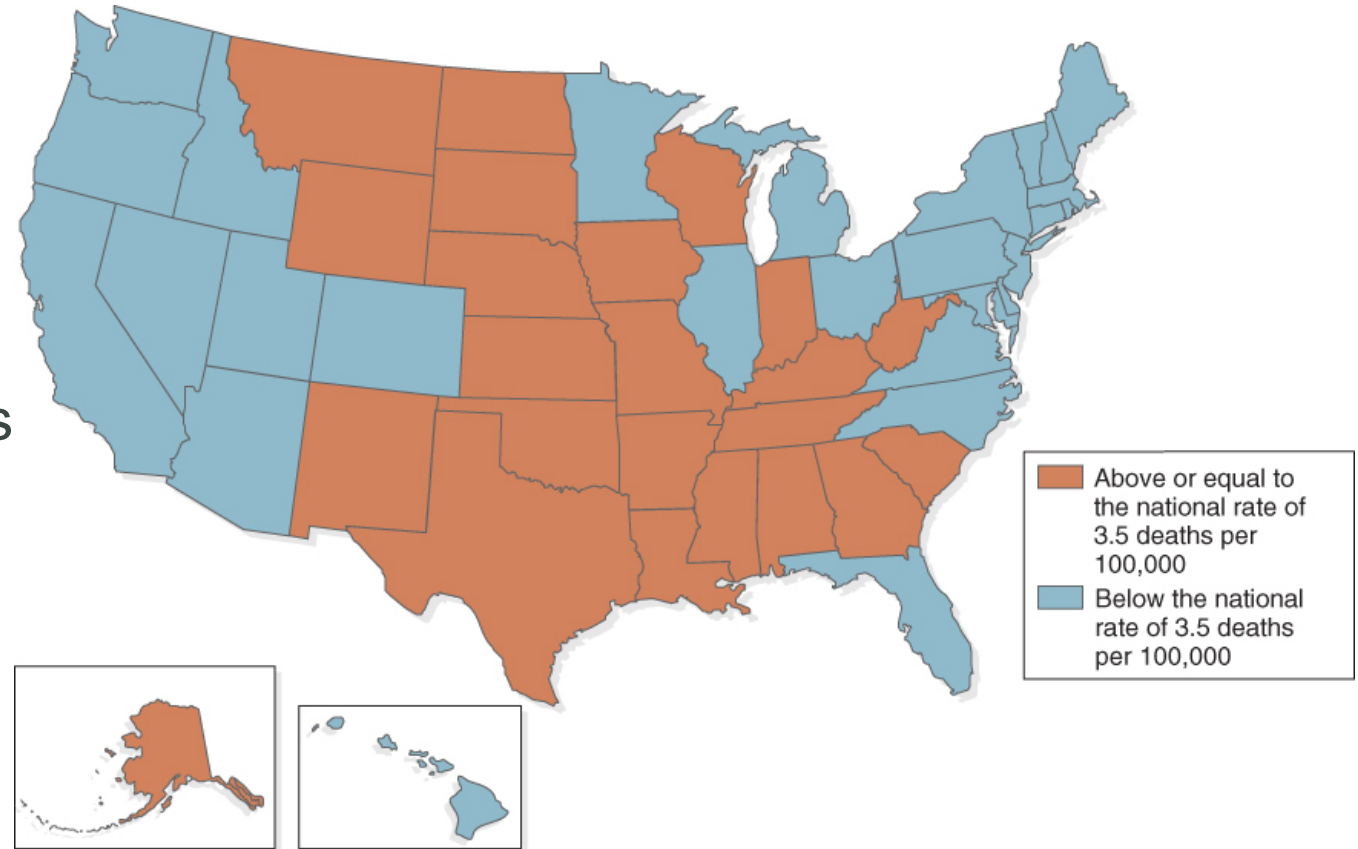
6.2 Toxic Metals

**6.3 Hazards in the Workplace**

6.4 Management of Hazardous Products and Byproducts from  
Manufacturing

# Occupational Fatalities

- 3.5 deaths per 100,000 U.S. workers in 2018<sup>85</sup>
- Half of all deaths involved a vehicle
- Other causes: falls, slips, trips, and violence and other injuries by persons or animals
- Occupational statistics fail to show work contribution to death from heart disease or cancers, especially lung.

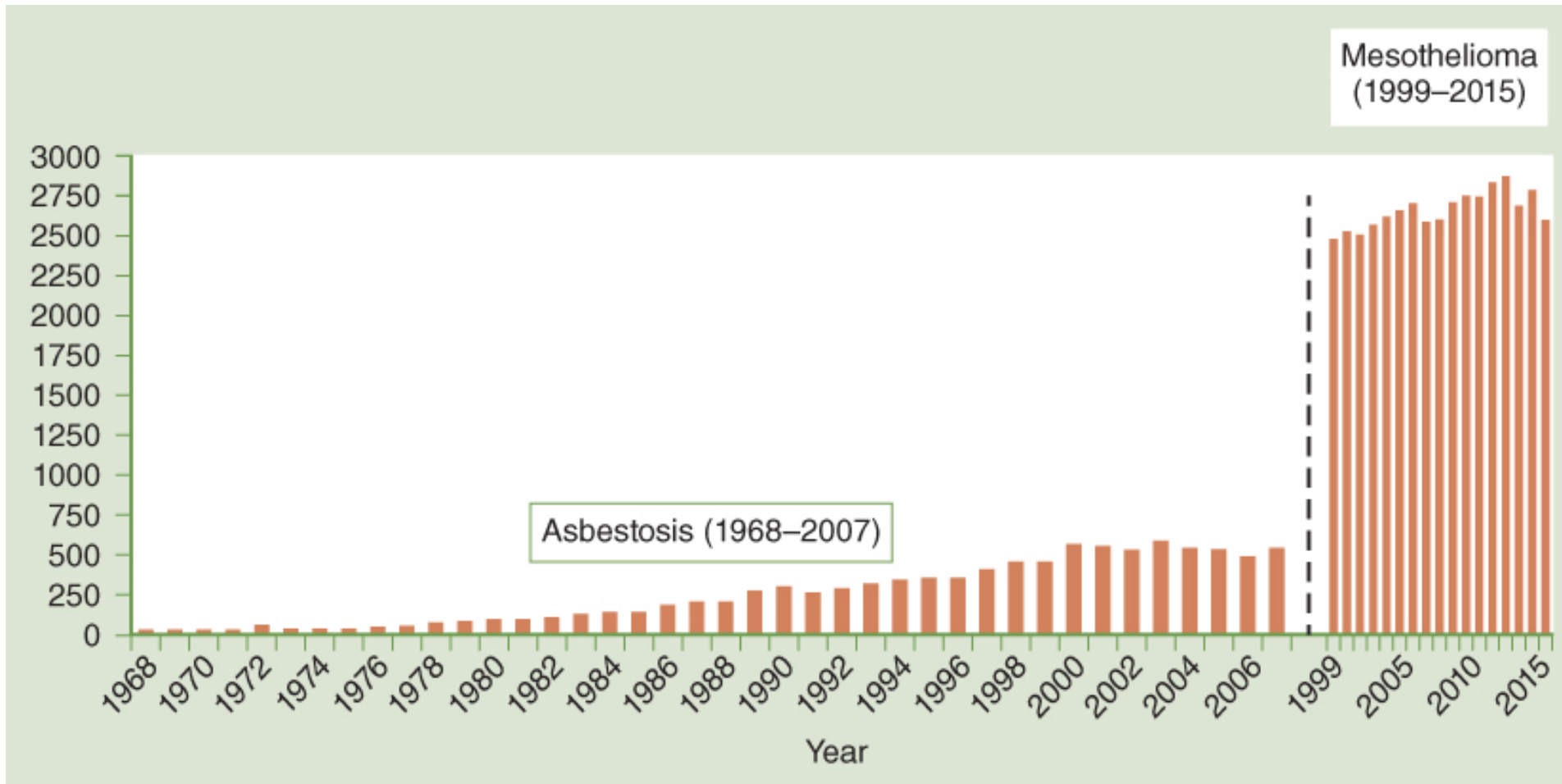


**FIGURE 6.8** Map of U.S. 2018 fatality rates.

Data from Centers for Disease Control and Prevention. Fatal Injuries Charts. Retrieved from: <https://www.cdc.gov/NIOSH-WHC/chart/bls-fw?T=ZY&V=C&S=N00>

# Asbestos Fibers

- Mineral fiber; insulating, noncombustible
- Widespread occupational exposure
  - Mining, manufacturing, construction, shipbuilding, auto repair; workers' families also exposed
- Asbestosis, lung cancer, mesothelioma (sentinel illness for asbestos exposure)
- Control lagged behind understanding; high exposures today in less-developed countries



**FIGURE 6.9** Deaths with asbestosis or mesothelioma as underlying cause.

Data from Mortality multiple cause-of-death data from National Center for Health Statistics, National Vital Statistics System. Population estimates from U.S. Census Bureau; see Appendix ([www2a.cdc.gov/drds/WorldReportData/Appendix.asp](http://www2a.cdc.gov/drds/WorldReportData/Appendix.asp)) for information about data sources, methods, ICD codes, and limitations for general caution regarding inferences based on small numbers of deaths. Reference Number: 2012F01-01.



# Cotton Dusts

- Cotton mill workers
- Fibrotic lung disease: byssinosis (“brown lung”)
- Disabling but not highly fatal<sup>95</sup>
- Common today in less-developed but rapidly industrializing countries<sup>96,97</sup>

# Asthma-causing Agents in the Workplace

- Metals and physical agents such as dusts or fibers are known as causes of **occupational asthma**.
- Organic compounds, particularly isocyanates
  - Used as paint-hardening agents and as the raw materials for polyurethane foam and various adhesives and coatings<sup>98-100</sup>
- Other substances known to cause or aggravate asthma include flour and wood dust; organic compounds used as cleaning agents; metal-working fluids, iron welding fumes, and solder flux (the substance used to promote joining); aluminum (e.g., in solder); chromium and nickel (used in electroplating); latex in gloves; and gluteraldehyde (in sterilizing agents).<sup>99,100</sup>
- Working as a printer, baker, sawmill worker, metal processing plant worker, spray painter, hairdresser, welder, or farmer is associated with increased asthma risk.<sup>101,102</sup>

# Noise – Unwanted Sound

- Effects on hearing
  - Threshold shift: upward shift in threshold at which sound at certain frequency can be perceived
  - Tinnitus (ringing or other sound in the ears) after exposure to loud noise
- >10% of currently employed workers experience hearing difficulty.
- Highest–hearing-loss industries: agriculture, forestry, and fishing<sup>85</sup>
- Military service linked to hearing loss.<sup>111, 112</sup>
- Other workplace noise effects include lapses in memory, attention, or perception; coronary heart disease; angina (chest pain caused by inadequate blood supply to the heart); and heart attack.

# Light During the “Biological Night”

- Shift work can disrupt circadian rhythms: basic physiologic day/night cycle
  - Common in varied sectors: manufacturing, finance, real estate, food services <sup>115</sup>
- IARC classifies “shift work that involves circadian disruption” as Group 2A carcinogen.<sup>116</sup>
- In rodents, light-at-night linked to increase in body mass index.<sup>119</sup>

# Reproductive Occupational Hazards (1 of 3)

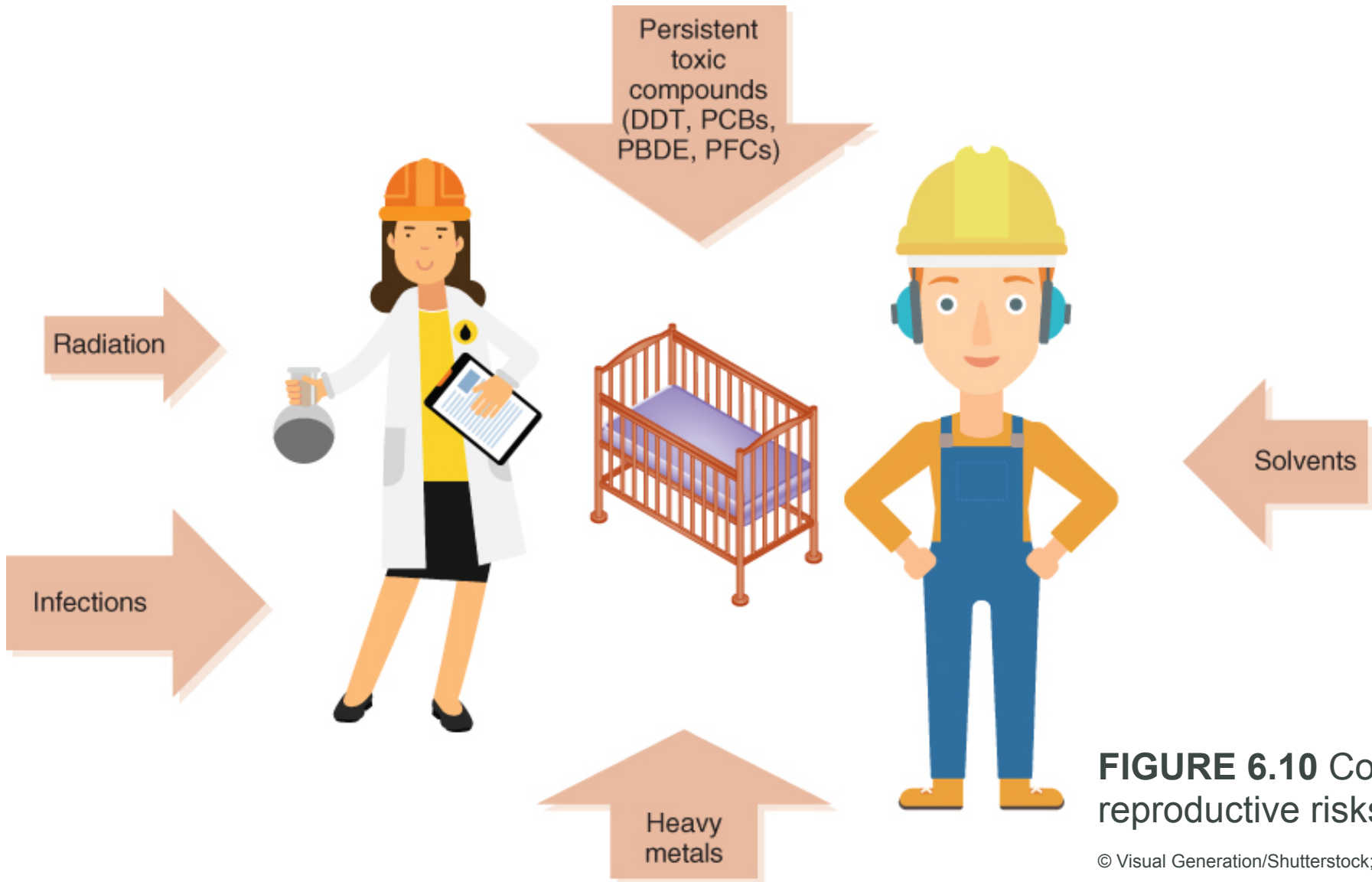
- Shift-work identified as a reproductive hazard, as circadian dysregulation is linked to irregular menstrual cycles, endometriosis, infertility, miscarriage, low birth weight, or pre-term delivery<sup>120</sup>
- Radiation known to cause miscarriage or act as a **teratogenic agent** (causing birth defects)
  - Occurs among X-ray technicians, dental hygienists, and imaging laboratory workers<sup>121</sup>
- Occupation may expose workers to infectious teratogenic agents, particularly health care workers, social workers, teachers, butchers, and animal handlers.
- Virtually all organic solvents are known to harm the reproductive system.
  - Increase risk of miscarriage, stillbirth, preterm birth, a low birth weight baby, or a baby born with a birth defect
  - Many organic solvents are also known to pass into breast milk.<sup>122</sup>
- Endocrine-disruptors associated with adverse reproductive outcomes
  - Phthalate plasticizers shown to disrupt ovarian function in mice at doses equivalent to human exposure related to phthalate coatings on certain medications. <sup>121</sup>

# Reproductive Occupational Hazards (2 of 3)

- Persistent chemicals one of the first to be associated with reproductive risks
  - Carson described the thinning of eagle egg shells associated with DDT.
  - Agricultural workers, both males and females, face a variety of reproductive risks associated with their exposures not only to persistent pesticides such as DDT, but also to dioxins from the manufacture of pesticides.
  - Risks from pesticides include infertility, miscarriage, small-for-gestational age, preterm delivery, low birthweight, and stillbirth.
- PBDE chemicals with damaging male reproductive hormone production

# Reproductive Occupational Hazards (3 of 3)

- PFOA linked community exposure to pregnancy-induced hypertension.
  - Risk factor for prematurity and low birthweight
  - Co-occurrence of mercury with PFOA potentially increases neurologic risks during *in utero* development.
  - Worker exposure has the potential to be higher than these risks observed among the general population.
- Lead has been associated with miscarriage and premature birth in human studies.
  - Other metals that pose reproductive risks include nickel, cadmium, mercury, and possibly arsenic.
- Silver nanoparticles have reproductive and developmental toxicities, such as delayed cognitive behavior.
  - Detection of silver nanoparticles in the testes, the placenta, and breast milk following injection has raised concern about their ability to migrate and become bioavailable.
  - Titanium and silver concentrations associated with nanoparticle ingestion have also recently been associated with neural tube defects in offspring.



**FIGURE 6.10** Contributors to occupational reproductive risks.

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6.1 Synthetic Organic Chemicals

6.2 Toxic Metals

6.3 Hazards in the Workplace

**6.4 Management of Hazardous Products and Byproducts from Manufacturing**

# ***Industrial Pollution and Workplace Exposures in the United States***

*The Global Disparity in Protections for Workers*

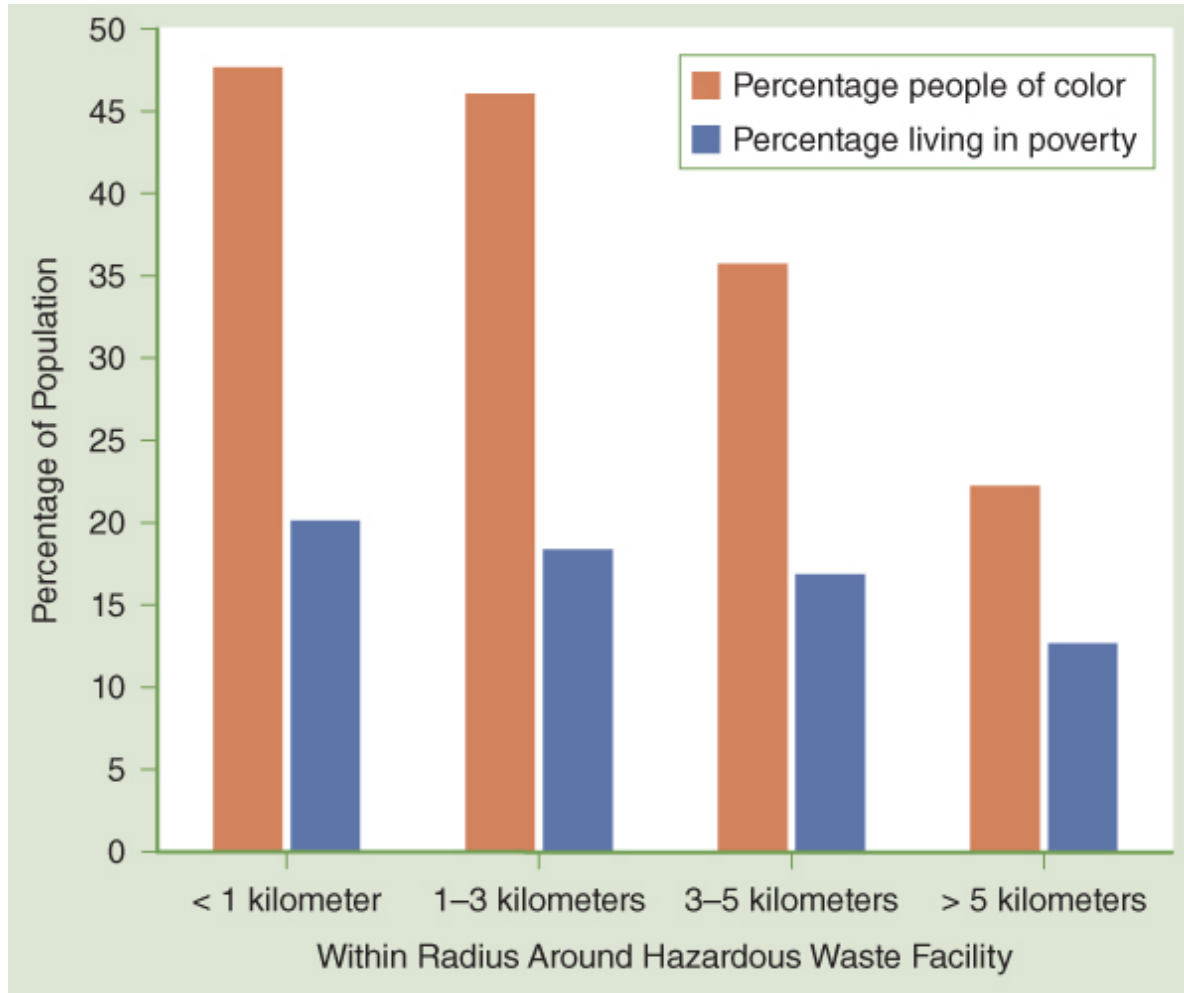
*Managing Industrial Pollution*

*Managing Workers Health*

*Regulation of the Manufacture and Use of Chemicals*

# Industrial Pollution/Workplace Exposures

- Social disparities (race, poverty) in
  - Industrial pollution and occupational hazards
  - Particulate air pollution
  - Disposal of hazardous wastes
- Regional disparities in burden of coal mining, uranium mining



**FIGURE 6.11** Demographic disparities in residential proximity to hazardous waste facilities in the United States, 1990.

Data from Bullard R, Mohai P, Saha R, Wright B. Toxic Wastes and Race at Twenty: 1987–2007. United Church of Christ, Justice & Witness Ministries. 2007; Table 3.1. Available at: [www.ejrc.cau.edu/TWART%20Final.pdf](http://www.ejrc.cau.edu/TWART%20Final.pdf). Accessed April 17, 2008.

*Industrial Pollution and Workplace Exposures in the United States*

***The Global Disparity in Protections for Workers***

*Managing Industrial Pollution*

*Managing Workers Health*

*Regulation of the Manufacture and Use of Chemicals*

# Global Disparity in Protections for Workers

- More developed countries export hazards to avoid costs of managing them.
- Workers in less-developed countries bear heavy burden of illness and injury.
  - Shipbreaking
    - In India and Bangladesh, to extract scrap metal
  - Recycling of used computers (eWaste)
    - In China and India, to extract salable components
- Basel Convention on the Control of Transboundary Movements of Hazardous Wastes and Their Disposal



**FIGURE 6.12** Manual laborers break down beached ships on the shore of Bangladesh.

Courtesy of Pierre Claquin.

*Industrial Pollution and Workplace Exposures in the United States*

*The Global Disparity in Protections for Workers*

***Managing Industrial Pollution***

*Managing Workers Health*

*Regulation of the Manufacture and Use of Chemicals*



# Moving Upstream: Cleanup of Abandoned Hazardous Waste Sites

- Superfund (CERCLA) passed 1980 and amended as SARA in 1986
- EPA identifies abandoned hazardous waste sites
  - Placed on National Priorities List
  - Site assessment, including risk assessment
  - If possible, *polluter pays* for assessment and cleanup; if not, the Superfund pays.

# Cleanup of Abandoned Hazardous Waste Sites



**FIGURE 6.14** Drums of toxic wastes litter a Superfund site in this undated photo.

Courtesy of CDC Public Health Image Library. ID# 1193. Content provider: CDC. Available at: <http://phil.cdc.gov/phil/home.asp>. Accessed October 15, 2012.

# Controls on Current Discharges of Manufacturing Wastes (1 of 2)

- Land disposal of hazardous wastes: Resource Conservation and Recovery Act
  - Applies to specific wastes listed by EPA
  - And to any waste that is ignitable, corrosive, reactive, or toxic (according to criteria)
  - Requires “cradle-to-grave” tracking of hazardous wastes; performance requirements for landfills

# Controls on Current Discharges of Manufacturing Wastes (2 of 2)

- Discharges to air: Clean Air Act
  - Criteria Air Pollutants, Hazardous Air Pollutants
- Discharges to water: Clean Water Act
  - Federal standards for ambient water quality (Ambient Water Quality Criteria [AWQC])
  - Requirement to use “best available technology” to meet standard
  - States set permit requirements for discharges, to meet AWQC and technology requirement
  - Law distinguishes point, nonpoint sources

*Industrial Pollution and Workplace Exposures in the United States*

*The Global Disparity in Protections for Workers*

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# Controls on Workplace Hazards (1 of 3)

- OSH Act (1970): requires most employers to provide workplace “free of recognized hazards”
- Focus on mechanical hazards, chemical inhalation hazards
- OSHA sets Permissible Exposure Limits (PELs).
  - Time-weighted average, short-term exposure limit, ceiling

# Controls on Workplace Hazards (2 of 3)

- NIOSH produces Recommended Exposure Limits (RELs), intended as basis for OSHA's PELs.
- ACGIH produces Threshold Limit Values (TLVs, also time-weighted average).
- Process of deriving PELs from RELs (or TLVs) has foundered.

# Controls on Workplace Hazards (3 of 3)

- OSH Act gives modifications to work environment priority over personal protective equipment.
- Employers must provide workers training and information on chemical hazards.
  - Materials Safety Data Sheet (MSDS)



*Industrial Pollution and Workplace Exposures in the United States*

*The Global Disparity in Protections for Workers*

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*Managing Workers Health*

***Regulation of the Manufacture and Use of Chemicals***

# Toxic Substances Control Act, 1976

- Precautionary: before manufacturing new chemical, company must notify EPA
- EPA can restrict manufacture, distribution, use of chemical
- In practice, EPA has restricted only five chemicals (or sets of chemicals)
- Issues: corporate confidentiality as barrier; EPA's lack of resources

# Pollution Prevention and the Precautionary Principle

- Pollution Prevention Act (1990)
  - Named source reduction (waste prevention) as preferred option over treatment/disposal
  - Created Office of Pollution Prevention in EPA
  - Had little effect
- In 2009, EPA announced new principles for managing toxic chemicals
  - More precautionary, more transparent
  - Promotes green chemistry ideals
  - Future impact uncertain