Occupational Health

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Summer EH

Learning Objectives

• By the end of this lecture, you should be able to:
  – Define occupational health
  – Identify the main occupational injuries and illnesses and disease classics
  – Discuss the special characteristics of the occupational environment
  – Describe special approaches to occupational exposure limits and biological monitoring
  – Discuss enforcement of occupational regulations
Occupational Health

It is About People

- Persons in large workplaces
- Persons in small-scale businesses
- Self-employed
- Migrant workers
- Young (< 16 yr) and older (> 65 yr) persons
- Full-time & part-time & temporary
- Contracted
- Disabled
- Immigrants

In contrast to some views of environmental health:
protect the environment for the environment’s sake
Why Do We Work?

- Financial means to support oneself
- Our work is an important part of our identity
- Work can lead to personal growth, discovery, feelings of contributing to society
- Work provides social networks & support, relationships
- What are characteristics of a good job?
  - Rewarding, creative, autonomous, self-directed, supportive environment and co-workers, high salary, flexible work hours and locations, good benefits, diverse workforce, outdoors, safe for health?

- Should we expect that while we work our health will not be adversely impacted?
What is Occupational Health?
World Health Organization, 1950

• The promotion and maintenance of the highest degree of physical, mental, and social well-being of workers in all occupations;
• The prevention among workers of departures from health caused by their working conditions;
• The placing and maintenance of the worker in an occupational environment adapted to the worker’s physiological and psychological equipment;
• The adaptation of work to the worker and of each worker to the job.

Occupational Health: A Multidisciplinary Field

• Occupational medicine
• Occupational health nursing
• Industrial hygiene / safety science / ergonomics
• Employee Assistance Programs
• Health promotion / wellness programs
• Human resources
• Health benefits – integrating traditional money pools – employee health, workers’ compensation, health insurance, disability insurance
NIOSH-funded Johns Hopkins Education and Research Center for Occupational Safety and Health

Professional training programs

• Occupational & Environmental Medicine Residency
  – I work with Dr. Aisha Rivera to direct program
  – Two-year program: MPH + practicum year
  – ABMS specialty; American Board of Preventive Medicine

• Occupational & Environmental Health Nursing
• Occupational & Environmental Hygiene

Other training programs (PhD, research)

• Biomarkers of Occupational Exposure & Susceptibility
• Occupational Injury Epidemiology

A Brief (Western) History of Work

• In human history, demanding work was done by slaves
• Greeks considered work a curse
• Aristotle and Plato believed that men must toil so that the elite could engage in philosophy, the arts, and politics; leisure time was a measure of status
• “Working hard” was not a cultural value until The Reformation in Europe (16th C)
• A new industrial system was developed of long hours, poor working conditions, that enriched relatively few
• Industrial Revolution in UK (1800s) transitioned from hand to mechanized production, steam power, machine tools, factory system
• US eventually overtook UK to become world’s largest economy, especially after US Civil War (1860s)
Bernardino Ramazzini

- *The Diseases of Workers*, 1700
- Examined health risks in 53 occupations (e.g., metal workers, gilders, corpse-bearers, salt-makers, wood workers, printers, fullers, sedentary workers, soap-makers, weavers)
- He proposed physicians add to list of questions proposed by Hippocrates: “What is your occupation?”
- “Father of occupational medicine,” pioneer in preventive medicine too

Ramazzini (continued)

Early (now classic) descriptions of affected workers

- “…mercury miners can hold out for barely three years … become subject to palsy of the limbs …”
- “…first their hands become palsied, then they become paralytic, splenetic, lethargic, cachectic, and toothless, so that one rarely sees a potter whose face is not cadaverous and the color of lead”
- Tobacco workers “… dissections of corpses from which it appears what serious & horrible injuries to lungs & brain were found, caused by … smoking … & taking snuff”
- “… stonecutters … usually troubled with cough … asthmatic affectations and become consumptive … when bodies are dissected … lungs … stuffed with small stones”
Interesting Disease Discoveries in OH

A few examples; new hazards are regularly introduced

- Acute beryllium lung disease, 1930s, fluorescent lamps; chronic beryllium disease, 1950s and later, nuclear weapons national laboratories workers
- Plastic manufacturing, 1970s, vinyl chloride → lung, liver, and bone disease, and cancer including angiosarcomas of liver and elsewhere
- Male infertility U.S., dibromochloropropane pesticide manufacturing, 1970s, then in developing countries on plantations, 1990s
- Popcorn lung, bronchiolitis obliterans from butter flavoring, diacetyl, 2000
- Progressive inflammatory neuropathy, in pig workers, from inhalation of aerosolized pig brains in slaughterhouses, caused autoimmune response, 2006-08

Popcorn Lung

- Diacetyl and its substitute, 2,3-pentanedione, are widely used flavoring compounds; intensely butter-flavored
- First observation of serious lung disease probably from 1985 in a food production plant making flavorings for baking industry
- Increasing evidence through mid-2000s from microwave popcorn factories, flavor manufacturing, cookie manufacturing, coffee production, snack and candy factories
- Bronchiolitis obliterans; inflammatory disease of smallest airways (bronchioles) in lungs
- These chemicals are also found in cigarette smoke and some e-cigarettes
- US NIOSH announced recommended exposure limits in 2016; US OSHA has not passed any regulations
There is a lot to Know about the World of Work! Some Examples:

<table>
<thead>
<tr>
<th>Workplace Issue</th>
<th>Law / Regulation</th>
</tr>
</thead>
<tbody>
<tr>
<td>If you get sick or injured by a job, are you covered?</td>
<td>Workers' compensation laws</td>
</tr>
<tr>
<td>If you are disabled, should society help you get a job?</td>
<td>Americans with Disabilities Act</td>
</tr>
<tr>
<td>If you have a longer illness and cannot work, should your job be kept for you?</td>
<td>Family and Medical Leave Act</td>
</tr>
<tr>
<td>If you are disabled and can no longer work, are there any programs to help you?</td>
<td>Social Security Disability</td>
</tr>
<tr>
<td>If you lose your job and cannot find a new one, should society help cover economic losses?</td>
<td>Unemployment compensation laws</td>
</tr>
<tr>
<td>Should you be allowed to negotiate with your employer over the conditions of work?</td>
<td>Labor laws</td>
</tr>
<tr>
<td>Should you expect work to be safe?</td>
<td>OSHA, MSHA</td>
</tr>
<tr>
<td>Do you have a right to know about the chemicals you work with?</td>
<td>Right to Know laws OSHA Haz’d. Comm. Std.</td>
</tr>
</tbody>
</table>

Sectoral Organization of Economies

The jobs that people have are derived from these sectors

- **Tertiary Sector**
  - Services
    - Trade / Banking / Retail / Education / Transport / Health / Public Safety / Energy Production

- **Secondary Sector**
  - Production of Goods
    - Manufacturing / Crafts / Construction

- **Primary Sector**
  - Production of Materials
    - Agriculture / Fisheries / Mining / Forestry / Energy Extraction

As economies mature, move up pyramid.

U.S.: 77% of jobs in service sector

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How to Categorize the World of Work
According to U.S. NIOSH, April 2013
(Sector Program Areas)
Agriculture, Forestry, Fishing
Construction
Healthcare and Social Assistance
Manufacturing
Mining
Oil and Gas Extraction
Public Safety (law enforcement, firefighting)
Services (highly varied)
Transportation, Warehousing, Utilities
Wholesale and Retail Trade
International Health & Development

• Development since World War II has meant:
  – Industrialization & price-setting markets

• Industrialization involves:
  – Processing of materials & discharge of wastes
  – Air pollution, land degradation, water/soil toxification
  – Increasing occupational health problems

• The fruits of development:
  – Improve diet, overall level of physical comfort
  – Invest increased material wealth in social services, public health, medical care, water distribution, sanitation facilities

Kinds of Development Projects

• Roads & transport systems
• Water supply and sanitation
• Water resource development
  – Dams, irrigation - change distribution and flow of surface water
• Industrial facilities, mines
  – Multinationals in search of cheap labor, resources, new markets
• With development, see transition in public health hazards from traditional infectious to toxic, industrial
### Developed vs. Developing Economies

<table>
<thead>
<tr>
<th>Factor</th>
<th>Developed</th>
<th>Developing</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sectors</td>
<td>Service &gt; manufacturing &gt;&gt; agriculture</td>
<td>Extractive industries, manufacturing, agriculture</td>
</tr>
<tr>
<td>Economy</td>
<td>Consumer driven</td>
<td>Access to export markets; often highly dependent on few industries</td>
</tr>
<tr>
<td>Markets</td>
<td>Generally accessible</td>
<td>Protected</td>
</tr>
<tr>
<td>Workforce</td>
<td>Healthier, educated</td>
<td>Less healthy, less educated, more children</td>
</tr>
<tr>
<td>Exposures</td>
<td>Lower</td>
<td>Can be very high; severe occupational diseases</td>
</tr>
<tr>
<td>Regulations</td>
<td>Variably enforced</td>
<td>Absent or not enforced</td>
</tr>
<tr>
<td>Corruption</td>
<td>Subtle</td>
<td>Explicit</td>
</tr>
<tr>
<td>EH vs. OH</td>
<td>Approximately equal</td>
<td>Environment gets attention before worker health</td>
</tr>
<tr>
<td>Informal economy*</td>
<td>Less important</td>
<td>Very important</td>
</tr>
</tbody>
</table>

* Not taxed, not monitored by government, and not included in GDP

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### Manufacturing Shifts to Developing Countries

- Large multinational corporations control a large share of world’s total economic activity
  - In 2000, 51 of 100 largest economies in world were corporations, not countries; now likely worse

- Developing countries:
  - Large labor pools, far more than jobs; lower environmental standards; lower occupational health standards; usually lower taxes

- Multinational corporations “export” their hazards to the developing world as developed countries tolerate less

- Mechanization reduces costs and jobs in both developed and developing countries
Types of Environmental Exposures (or Factors, Stressors)

- Chemical hazards (toxicants)
  - Clinical toxicology
- Dusts and particulates
- Physical hazards
  - Temperature, pressure, vibration, radiation
- Ergonomic hazards
  - Exposure to these hazards causes work-related musculoskeletal disorders
- Biological hazards
  - Infectious, allergic, toxins
- Psychological hazards
- Safety hazards

<table>
<thead>
<tr>
<th>Factor</th>
<th>Occupational</th>
<th>Environmental</th>
</tr>
</thead>
<tbody>
<tr>
<td>Age</td>
<td>16-65 years</td>
<td>0-100 years</td>
</tr>
<tr>
<td>Health of exposed</td>
<td>Generally healthy</td>
<td>Entire range, including most susceptible</td>
</tr>
<tr>
<td>Epidemiologic issues</td>
<td>Healthy worker effect, survivor cohorts, selection bias</td>
<td>Generally not present</td>
</tr>
<tr>
<td>Types of exposures</td>
<td>Any imaginable</td>
<td>Generally a subset</td>
</tr>
<tr>
<td>Daily duration</td>
<td>8 hours</td>
<td>24 hours</td>
</tr>
<tr>
<td>Lifetime duration</td>
<td>Working lifetime</td>
<td>Lifetime</td>
</tr>
<tr>
<td>Intensity of exposure</td>
<td>Moderate to high</td>
<td>Low</td>
</tr>
<tr>
<td>Attention of the public</td>
<td>Less</td>
<td>Much more</td>
</tr>
<tr>
<td>The tensions</td>
<td>Jobs, jobs, jobs! Labor, management, regulators</td>
<td>Environmentalists, industry, regulators</td>
</tr>
</tbody>
</table>
Injury vs. Illness ("Disease")

• Different distinctions in different jurisdictions, but in general …

• **Injury**: short latency, acute transfer of energy (e.g., chemical, temperature, gravity, mechanical) to body ("single instantaneous exposure"), generally no uncertainty about causation
  – In U.S., some are reportable to government

• **Illness**: longer latency, multifactorial, complex causation, toxic, biologic, physical and other hazards, and not an injury
  – In U.S., all are reportable, but few likely recognized

NIOSH: 10 Leading Work-Related Diseases and Injuries, US (1980s)

• Occupational lung diseases
• Musculoskeletal injuries and disorders
• Occupational cancers
• Severe occupational traumatic injuries
• Cardiovascular diseases
• Disorders of reproduction
• Neurotoxic disorders
• Noise-induced hearing loss
• Dermatologic conditions
• Psychologic disorders
How About Internationally?

• > 350,000 workers die annually due to unintentional occupational injuries
  — > 90% of these deaths occur among men
  — > 50% occur in WHO SE Asia & Western Pacific regions (WHO, Global Health Risk, 2009)

• This does not nearly capture the full occupational burden
  — Non-fatal injuries
  — Diseases
  — Informal sector
Occupational Health

- Annual deaths: 2M occupational illnesses, 0.3M injuries
- Additional 160M annual non-fatal work-related diseases
- But data are not very good
- Several strategies: legally-required reporting by employers to governments; claims accepted by compensation schemes; information from practitioners providing surveillance services; national surveys
- All are quite poor worldwide, even in developed countries
- Without good counting it is impossible to develop sensible policy, regulations, interventions
- So occupational disease and injury are common, preventable, but rarely systematically addressed

ILO: UN agency dealing with work opportunity, labor standards, social protection, and health; most UN member states are members. Develops conventions (legally binding treaties) or recommendations (non-binding guidelines)

The Occupational Disease “Classics”

The workplace is where we usually first observed toxicological impacts

- Introduction of new hazards as humanity figured out the natural world and how to use it in the newly industrializing world
- Occupational risks eventually recognized, often long before modern scientific methods
- The history of these stories is often fascinating
- Many examples of poor corporate behavior
- Interesting clinical and pathophysiologic aspects
- The stuff we use everyday can be quite hazardous to make!
Mining and Extractive Industries

- Humans have been digging stuff out of the ground for thousands of years – surface or deep
- Geology and geologic processes provide a wealth of useful materials (non-renewable)
  - Examples: metals, coal, oil shale, gemstones, limestone & chalk (CaCO₃), finished stone, rock salt, potash (K), gravel, clay
- These industries are environmentally degrading
- Long history of occupational health impacts
- Cause several occupational diseases, dust-induced diseases of the lung: pneumoconioses
- Increasingly problematic in small-scale industries around the world

Yup, It Sure Is “CLEAN COAL” …

- Mountaintop removal and mining
  - Destructive practices, battered communities
- Air pollution
  - Acid rain, sulfur dioxide, nitrogen oxides, particulates, mercury
- Greenhouse gas emissions
  - More carbon intensive than other sources
  - Carbon capture and storage is a fantasy to date
- Ash generation
  - Huge waste stream
- Occupational issues
  - Black lung, underground explosions, injuries
The Pneumoconioses

- Coal worker’s pneumoconiosis (PMF)
- Silicosis – more on following slides (PMF)
- Asbestosis – more on following slides (PMF)
- Flock worker’s lung – from synthetic fabric manufacturing
- Hard metal disease – from hard metal alloy = primarily tungsten carbide and cobalt
- Chronic beryllium disease, clinically like sarcoidosis
- Talcosis – rare, form of silicate
- Aluminosis – aluminum dust, rare
- Baritosis – barium dust, generally benign
- Stannosis – tin oxide particles, generally benign
- Siderosis – iron particles, generally benign

PMF = progressive massive fibrosis – large fibrotic conglomerates in lung

Coal Mining and Occupational Health

- Coal is an inexpensive energy source
- It is the most carbon intensive of the fossil fuels
- Accounted for 30% of US electricity generation (2016); 91% of coal goes to electricity; ~20% of all US energy
- US has 28% of all world coal reserves
- Coal industry employs 183K in US, around 6M in China; estimated 5000 annual deaths in China
- Causes many lung diseases: “classic” coal worker’s pneumoconiosis ("black lung"), dust-related diffuse fibrosis, progressive massive fibrosis, emphysema, chronic obstructive pulmonary disease

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Silicosis

- Caused by inhalation of crystalline silica ($\text{SiO}_2$), world’s most abundant mineral (amorphous vs. crystalline forms)
- Three common forms of free crystalline silica in workplaces (quartz, tridymite, cristobalite)
- Quartz can occur alone or in other types of rock
- Respirable sizes < 10 $\mu$m aerodynamic diameter; disease risk is a function of cumulative dose (intensity x duration)
- Found in many industries: construction, mining, agriculture, car repair, foundries, arts, sculpture, casting/molding, ceramic, potteries, painting, roofing, many others (“dust from rock”)
- **One of most important occupational diseases in world;** most common occupational lung disease worldwide
- A type of **pneumoconiosis** (also called miner’s phthisis, grinder’s asthma, potter’s rot)

The Hawk’s Nest Incident

- Largest industrial disaster in US history
- Gauley Bridge, WV, 1930-32
- Tunnel construction for water diversion for power generation; silica content of rock > 90%
- Over 475 workers died; 1500 were disabled from chronic silicosis
- Work was done for a Union Carbide plant
- Same company involved in Bhopal disaster in India in 1984 (methyl isocyanate) – considered by many to be world’s worst industrial disaster (tens of thousands affected)

*View of Gauley Bridge, WV circa 1930*  
*Source: The Hawk’s Nest Incident, Cherniak M, 1986*
Silicosis Around the World

• Still occurring in developed countries, but big problem in the developing world

• **China**: has the most cases; >500,000 cases recorded 1991-95; 6000 new cases, 24,000 deaths annually; particularly problematic in small-scale mines, with accelerated form of disease

• **Brazil**: gold-mining, Minas Gerais, >4500 cases 1978-98

• **South Africa**: autopsy study, gold miners, 1975-2009, percent with silicosis on autopsy increased from 3 to 32% in black miners and 18 to 22% in white miners

• Quantitative risk assessment by US NIOSH: per 1000 persons exposed to OSHA limit (0.05 mg/m³) in 45y work
  – Lung cancer deaths: 19 cases
  – Lung disease: 54 cases
  – Silicosis: 75 cases

*Regulation is always a trade-off*
Silicosis Clinical Aspects

- Disease is fascinating clinically; occurs in acute and chronic forms
- Simple (nodular), progressive massive fibrosis, silicoproteinosis, and diffuse interstitial fibrosis forms
- Increases risk of several other health problems: tuberculosis, lung cancer, autoimmune diseases (rheumatoid arthritis, vasculitis, lupus, scleroderma), chronic kidney disease, COPD
- Much is understood about the pathophysiology, immunology, and mechanistic pathways

Early silicotic lesion, cellular nodule of dust-laden macrophages (X100)

Chronic silicotic nodule with concentric fibrosis in center and peripheral dust-laden macrophages (× 40)

OSHA•NIOSH
June 2012

HAZARD ALERT

Worker Exposure to Silica during Hydraulic Fracturing

The National Institute for Occupational Safety and Health (NIOSH) identified exposure to airborne silica as a health hazard to workers conducting some hydraulic fracturing operations during recent field studies.

Silica dust cloud by worker delivering sand from sand mover to transfer belt.

Silica dust clouds from delivery trucks loading into sand movers.

This is one method NIOSH uses to communicate newly identified risks and provide advice to employers about prevention of health impacts.

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Asbestos

- Six naturally occurring fibrous minerals (e.g., chrysotile, amosite, crocidolite) with high length to width ratios, in two groups: serpentine (wavy) & amphibole (needle-like)
- Modern use began 100+ years ago; very useful: heat, chemical, corrosion resistant; used in > 3000 products
- Health risks noticed early on; national bans started > 30 y ago; insurance industry stopped offering life insurance to asbestos workers; but use in developing world is increasing (despite availability of non-toxic substitutes)
- Occupational, environmental, “bystander” exposures
- Health: pleural plaques, asbestosis, lung cancer, other cancers, mesothelioma
- Controversies: potency of various fiber types; does chrysotile cause cancer; safe exposure levels; legal approaches to compensation
- 50+ countries now ban its use

Libby, Montana

- Vermiculite mine contaminated with asbestos
- Source discovered in 1919; at one time during W.R. Grace’s ownership, mine produced 80% of world’s supply
- Vermiculite is a mineral (a phyllosilicate); not all is contaminated by asbestos; found in attic insulation, lawn and garden products, fireproofing material
- One of largest environmental disasters in U.S. history
- Very serious occupational impacts and an estimated 1,000 town residents developed asbestos-related disease
- Site designated Superfund site in 2002; EPA Administrator declared a public health emergency in Libby in 2009, first time EPA had ever done this
- 35M U.S. homes and buildings estimated to contain Libby’s Zonolite insulation
Current Mining

- Canada, previously a large producer, stopped mining at its last two mines in Quebec in 2011
- In 2009, 9% of world production was from Canada
- In 2015, 2 million tons of asbestos were mined worldwide
- Russian Federation #1, 55% of world production
- Followed by China (20%), Brazil (16%), and Kazakhstan (11%)

The 3 asbestos epidemics: mining, use, “in place”

- Past exposures ensure that asbestos-related disease will continue for decades
- Incidence of male mesothelioma in US peak ~2300 cases/y around 2010, ↓ to 500 cases/y by 2055
- In 1995, Peto et al. predicted peak UK male deaths ~3K/y by 2020
- By 2000, Peto et al. forecast 250K male deaths from mesothelioma in Western Europe by 2035
- Most deaths expected among roofers, plumbers, electricians, carpenters, gas fitters = building trades
- Others predict 10,000 cases/y among UK men by 2020
- “The history of asbestos related disease still has some distance to travel”
Asbestos Can Still be Found in Consumer Products

*Environmental Health News, July 8, 2015*: “Is your child coloring with asbestos? Cancer-causing asbestos fibers were found in several children’s crayon brands … all sold in the US.”

- Asbestos first found in crayons in 2000; new study finds it is still there; no regulations ban it from consumer products
- Found in four brands of 28 boxes of crayons tested (all manufactured in China)
- Average U.S. child wears down 730 crayons by age 10 years, and sometimes children eat crayons
Newly Identified Occupational and Environmental Lung Diseases Continue to Occur

Table 1. Environmental and occupational lung diseases that have been reported since 2008

<table>
<thead>
<tr>
<th>Disease</th>
<th>Exposure setting</th>
<th>Responsible agents</th>
<th>Country</th>
</tr>
</thead>
<tbody>
<tr>
<td>Asbestos-related lung disease</td>
<td>Home residents [3**.4]</td>
<td>Tremolite</td>
<td>Turkey</td>
</tr>
<tr>
<td>Silicosis</td>
<td>Demin sandblasting workers [5–7]</td>
<td>Silica</td>
<td>Turkey</td>
</tr>
<tr>
<td>CWP</td>
<td>Surface coal miners [8]</td>
<td>Coal dust</td>
<td>USA</td>
</tr>
<tr>
<td>ID</td>
<td>Workers in paint plant [9]</td>
<td>Aerosolized polycrylate nanoparticles</td>
<td>China</td>
</tr>
<tr>
<td>Asbestomycosis</td>
<td>Home residents [10,11*]</td>
<td>SPF</td>
<td>USA</td>
</tr>
<tr>
<td>HP</td>
<td>Animal feed industry [12]</td>
<td>Phytase enzymes</td>
<td>Switzerland</td>
</tr>
<tr>
<td>Flockworker’s lung</td>
<td>Nylon workers [13]</td>
<td>Short length synthetic fibres</td>
<td>USA, Canada</td>
</tr>
<tr>
<td>Bronchiolitis obliterans</td>
<td>Consumers exposed to butter-flavoured microwave popcorn [14]</td>
<td>Diacetyl</td>
<td>USA</td>
</tr>
<tr>
<td>Bronchiolitis obliterans</td>
<td>Deployed soldiers returning from Iraq and Afghanistan [15]</td>
<td>Smoke from sulphur fire and burn pits (T)</td>
<td>USA</td>
</tr>
<tr>
<td>PAP</td>
<td>Indium processing workers [16]</td>
<td>Indium-tin oxide</td>
<td>USA</td>
</tr>
<tr>
<td>Sarcoidosis</td>
<td>WTC responders [17]</td>
<td>WTC dust</td>
<td>USA</td>
</tr>
</tbody>
</table>

In the table, CWP refers to coal workers’ pneumoconiosis, ID to interstitial lung disease, and PAP to pulmonary alveolar proteinosis.

Author’s Key Points
- New & old occupational lung diseases will continue to emerge & re-emerge because new technologies & chemicals continue to be introduced into workplace.
- Occupational lung diseases of global importance include asbestos-related disease, silicosis, coal worker’s pneumoconiosis, & heavy metal-induced diseases.

Benzene – C₆H₆, aromatic ring
- In industrial use since late 1800s; first chemical discovered to affect health of large numbers of workers
- Coal → high temperature heating → coke + chemicals melted out of coal, termed coal tar, including benzene; huge quantities are used industrially
- Very little around before industry
- Used as solvent: rubber, inks, glues, paints; and reactant
- Bone marrow is primary target (red blood cells, white blood cells, platelets): aplastic anemia, pancytopenia, myelodysplastic syndrome, leukemia, possibly myeloma, lymphoma
- Early exposed workers: bleeding disorders
- Now important environmental exposure too (gasoline, tobacco, wood-burning)
- Leukemia: acute, chronic; lymphocytic, myeloid, others – benzene causes several forms

Occupational Health

**Occupational Bladder Cancer**

- Synthetic dye industry began in Germany in 1860s, beautiful colors
- By 1895, German surgeons noticed that 1 in 10 industrial dye factory workers had bladder cancer
- By 1930, link was so clear that Switzerland and Germany made bladder cancer one of the first compensable occupational diseases
- After WW-I, US government seized patents and plants of German industry and sold to US companies at low costs

| Benzidine | Aniline (from coal tar) | 8-Naphthylamine, used to make azo dyes (R-N=N-R', R can be aryl or alkyl) |

**Bladder Cancer (continued)**

- US companies ignored cancer risk until cases began occurring
- First cases recognized by DuPont physicians in 1930s; by 1981, > 310 cases identified at Chambers Works
- Now much known about how these chemicals are metabolized and role of acetylation phenotypes (slow $\rightarrow$ ↑ risk)
- *Davis:* Nixon’s “war on cancer” went after diagnosis and treatment rather than causes, because this suited manufacturing companies

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Diisocyanates and Health

- **Four primary lung diseases**
  - Two types of occupational asthma, hypersensitivity pneumonitis, chronic obstructive pulmonary disease
- **Occupational asthma**: one of most common occupational diseases
- Incidence of TDI asthma before 1985 was > 10%, now likely < 1%
- Diisocyanates (-N=C=O) are **highly reactive compounds**
  - Bind to albumin, make adduct (serum albumin conjugate), IgG and IgE antibodies reactive to it (*JACI* 1999); useful biomarker of exposure & risk
  - Not the whole story though; complex pathways & immunology
- Because **sensitization** (immune system) is involved, can happen at **very low levels** of exposure (< 1 ppb)
  - Among lowest of workplace exposure limits
- **Genetic susceptibility** likely involved (GST [glutathione S-transferase], NAT [N-acetyl transferase], and other genes)
- Are also present in some **consumer products**; US EPA has investigated risks – difficult to characterize (US EPA, 2011)

OEHHA, CA EPA, 2014
• Methylene chloride is a volatile organic compound (VOC)
• It is an excellent solvent
• It is metabolized in body to carbon monoxide
• CO binds to heme in hemoglobin
• Forms carboxyhemoglobin – a biomarker
• Impairs oxygen carrying of blood
• In enclosed spaces where people often use solvents containing MeCl, air levels can get quite high
“Rare” Earth Elements: More Metals

17 elements – lanthanides + scandium & yttrium

Many high tech uses
- aerospace alloys
- batteries
- capacitors
- cell phones
- CFLs
- electric cars
- flat screen TVs
- lasers
- magnets
- superconductors
- wind turbines

- 95% of world production in China
- Environmental impacts to produce
- World production increasing
- Health concerns to follow?

Emerging Issue: e-Waste

- Metals in e-waste include: Ag, Al, As, Au, Cd, Cr, Cu, Fe, Hg, In, Ni, Pb, Ru, Se, Sn, V, Zn
- E-waste is fastest growing source of municipal solid waste; 20-50M tons annually of TVs, computers, monitors, cell phones, keyboards, printers, copiers
  - US 2.5M ton (2007) with 80% to landfills, 2% incinerators
- Huge production volume but limited management programs in place → mixed exposure, uncontrolled
- Some international efforts to reduce toxicants in electronics manufacturing, take back policies
- Basel Convention limits trans-boundary movement of hazardous waste, but still occurs; many developing countries with nascent recycling facilities – China, India, Ghana, Nigeria
E-Waste: Crossroads of Occupation & Environment

• China is world’s largest electronics manufacturer and also its “dumping ground” for wastes and recycling for electronics
• Heavily concentrated in southeast China
• Most is done in the informal sector – legal, publicly-accepted, unregistered – who use illegal processes
  – Strong acid leaching, open air burning
• Very few studies of workers; increasing evidence about environmental consequences – air, water, food – and biomarker and health studies in children
• Metals persist in environment and can bioaccumulate
• Evidence that these operations are contributing to distribution of metals regionally throughout southeast
• Increasing evidence on As, Cd, Cr, Cu, Hg, Pb, Ni, Zn

E-Waste: Vulnerable Populations

• E-waste recycling is organized around high throughput and output
• Most e-waste recyclers, in formal or informal sector, are poor, less educated than general population in area
• Poor children and women, especially in urban areas, represent a large portion of workers
• Exact numbers are difficult to determine, but children are considered ideal for e-waste recycling work because small dexterous hands facilitate dismantling of e-waste
• Children are also very susceptible to the hazardous exposures in e-waste work; more absorption, higher doses compared to body weight, growing body at higher risk, play outdoors in areas where work is going on
Vulnerable Populations: Modern Slavery

- 2016: 40.3M people in modern slavery
  - 15.4M in forced marriage
  - 24.9M in forced labor
  - Overall, 71% female; includes children
- Human trafficking, sexual exploitation

Drivers: consumerism, repressive governments, conflict, lack of basic needs, inequality, disenfranchised groups
- Climate change will increasingly drive these
- Highest risk products
  - Electronics, garments, fish, cocoa, sugar cane
- By far, U.S. consumers use much more of these than citizens of other countries

'It Was As if We Weren’t Human.' Inside the Modern Slave Trade Trapping African Migrants

The trade in human beings thrives on the road to Europe

TIME
March 14, 2019

African day laborers, part of caporalato system of cheap labor, in fields around Foggia, Italy

African migrants in Mediterranean Sea, 25 miles off Libyan coast, August 20, 2016
Preventing Occupational Injury and Illness
Hierarchy of Controls

Figure 1. Hierarchy of Controls [NIOSH 2015]

Ambient & Biological Monitoring

<table>
<thead>
<tr>
<th>Ambient Monitoring</th>
<th>Biological Monitoring</th>
<th>Patient Diagnosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>External Exposure</td>
<td>Internal Dose</td>
<td>Clinical Disease</td>
</tr>
<tr>
<td>chemical, biological, physical agents in air, water, soil, food</td>
<td>DNA adducts, protein adducts</td>
<td>anemia, cough up blood, jaundice, hand weakness, skin rash, protein in urine</td>
</tr>
</tbody>
</table>

INCREASING SIGNIFICANCE FOR HEALTH

Adapted from Angerer et al, Int J Hyg Env Hlth 210: 201, 2007
The Continuum for Surveillance: A Framework

EXPOSURE → EARLY BIOLOGIC EFFECTS → EXPOSURE MONITORING

SUBCLINICAL HEALTH EFFECTS → 1ST CLINICALLY DETECTABLE EFFECTS → BILOGIC MONITORING

MINOR CLINICAL DISEASE → HEALTH EFFECTS MONITORING

(MAJOR CLINICAL DISEASE) → (DEATH)

Schematic: Worker Exposure Over Time

Peak TWA = 90 µg/m³
Cumulative exposure = 1,000 years-µg/m³
Lifetime average TWA exposure = 50 µg/m³
Occupational Health

**Occupational Exposure Limits**

- **Permissible exposure limit (PEL)** – US OSHA standard; represents an allowable exposure level in workplace air averaged over an 8-hour period (time-weighted average, TWA)
- **Recommended exposure limit (REL)** – US NIOSH; based on best available evidence
- **Threshold limit value (TLV)** – airborne concentrations of substances; represents conditions under which nearly all workers may be unaffected – ACGIH (guideline)
- **Biological exposure index (BEI)** – measure of amount of chemical absorbed into the body – ACGIH (guideline)

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**The Failure of Regulation of Chemicals at U.S. OSHA**

*Similar story in all countries*

- **2,238 high-use chemicals**
- **1M pounds each**
- **470 have OSHA exposure limits.**
- **208 have OSHA exposure limits.**

Legal limits often looser than ACGIH voluntary limits

<table>
<thead>
<tr>
<th>Type of Limit</th>
<th>Number of Chemicals</th>
</tr>
</thead>
<tbody>
<tr>
<td>10+ times looser</td>
<td>36 chemicals</td>
</tr>
<tr>
<td>Up to 10X looser</td>
<td>171 chemicals</td>
</tr>
<tr>
<td>Same level</td>
<td>174 chemicals</td>
</tr>
<tr>
<td>Up to 10X tighter</td>
<td>14 chemicals</td>
</tr>
<tr>
<td>10+ times tighter</td>
<td>2 chemicals</td>
</tr>
</tbody>
</table>

ACGIH = American Conference of Governmental Industrial Hygienists

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**Biologic Monitoring**

- The measurement and assessment of agents or their metabolites in tissue, secreta, excreta, or expired air, to evaluate exposure and health risks compared to an appropriate reference.
  - Reference most often Biologic Exposure Index (BEI) of the ACGIH
- Only possible when sufficient toxicologic information available on mechanism of action and on fate of chemical
  - BEIs available on far fewer agents than are exposure limits

**Advantages of Biologic over Exposure Monitoring**

- Closer to health effect (disadvantage too)
- Integrates ROUTES of exposure
- Integrates SOURCES of exposure
- Captures effects of PERSONAL PROTECTIVE EQUIPMENT
- Captures INDIVIDUAL VARIABILITY in work practices
- Captures INTER-INDIVIDUAL VARIABILITY in toxicokinetics

*Disadvantage:* is secondary, not primary, prevention
Clinical Applications of Biomarkers

- Patient I evaluated
- 99 page report
- Hundreds of measurements, e.g., metals, organics
- Non-standard specimens (e.g., provoked urine, packed erythrocytes)
- Patients ask me what to do about elevations
- Many patients have been advised they need chelation therapy or "detoxification"

Health Effects Monitoring

- There are very few specific health effects of workplace exposures
- Generally use standard clinical tests to evaluate health effects in workers
  - Examples: liver function tests; pulmonary function testing (spirometry); hearing tests; chest x-rays; complete blood counts
- Must thus consider issue of low prevalence of disease in working populations and low positive predictive value of testing when low prevalence
  - If prevalence = 1%, sensitivity = 90%, and specificity = 90%, PPV = 9%
  - Only 9% of people with positive test have disease
Regulation to Protect Workers

- In most countries, government-related inspectors evaluate whether workplaces comply with regulations to protect workers
  - In U.S., OSHA can set regulations; inspect workplaces; cite employers; and fine employers
  - Regulation, inspection, & threat of citation supposed to deter workplaces to protect workers
- In U.S., many laws: OSH Act 1970; MSH Act 1969; Toxic Substances Control Act 1976; others (EPA, DoT, or Nuclear Regulatory Commission)
- OSHA has historically been a political lightning rod
- Worker’ Compensation laws can also be effective – make unsafe workplaces expensive for employers

Prevalence of coal worker’s pneumoconiosis 1970-2009, by tenure in coal mining: regulations can work

- Chest x-ray category 1 or greater (ILO B-reading method)
- Prevalence declined
- Concern about increases after 1995; NIOSH investigating
The Deadliest Threats Facing Workers

The Diseases People Bring to Work

- Could increase risk of adverse health effects from workplace exposure
  - Should people with asthma be allowed to work around TDI?
- Could impact the worker’s fitness-for-duty
  - Can someone with heart disease be a fire fighter?
- Could put the public at risk, public-safety sensitive jobs
  - Should pilots be excluded from flying with any history of mental illness?
- Can cost employers a lot more money
  - Should they be allowed to not hire?
- In US and Europe, many relevant regulations: in US: FAA, DoT, ADA, NRC, others

Germanwings crash: Co-pilot ‘treated for depression’

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Employment conditions are social determinants of health

- Wages
- Hours of work
- Workload and stress levels
- Interactions with coworkers and supervisors
- Access to paid leave
- Health-promoting workplaces

*All have an important impact on the well-being of workers, their families, and their communities*

Integration of many programs

- Occupational health & safety
  - Focus on workplace issues
- Employment
  - Preserve human resources
  - New programs, benefits, work patterns
- Workers
  - Promote worker health & well-being

The Impacts on Work and Costs

- Health conditions often categorized as
  - **Acute**: flu, colds
  - **Chronic episodic**: asthma, depression, pain, migraine, allergies, GERD
  - **Chronic**: heart disease, COPD, diabetes

- Health impacts often categorized as
  - Direct medical costs (medical, pharmacy)
  - Indirect costs – work absence, reduced performance at work (“presenteeism”)
  - Short- and long-term disability costs

- Non-medical issues can also impact work
  - **Work-life balance** issues; child care; family health; elder care; financial challenges
  - Many employers now have flexible programs to address these too

- Strong link between health and productivity at work
  - Presenteeism costs exceed direct medical costs by 2-3 fold
  - Large, interesting published literature
  - **Preventive medicine** and **population health** of working populations

GERD = gastroesophageal reflux disease; COPD = chronic obstructive pulmonary disease
Smoking cessation
Flu vaccine
Weight loss programs
Nutritional programs

- Engage and involve employees
- Empower employees
- Environmental supports
- New mothers room policy
- Flexible work arrangements
- Policies on seat belts, driving, texting, phoning
- Healthy living program design with health risk assessment and phone tracking
- Subsidized Weight Watchers
- Onsite fitness or subsidized gym membership
- Support groups – eldercare, disability
- Integrate with benefits, OS&H, EAP, and other programs
- Offer rewards and apply penalties if not meeting health goals, health costs

Volpp et al. NEJM 2011.