Chemical, Physical and Biological Exposures

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The Environmental Health Paradigm

How exposures cause disease and how we can reduce exposure or response to prevent disease (improve the health of the public)
Toxicology

- Exposure
- Internal dose
- Biologically effective dose
- Early biological effects
- Altered structure and function
- Clinical disease
EH Paradigm = Tox Paradigm

The Toxicological Paradigm
After the agent gains access to the body

Exposure

Internal dose

Biologically effective dose

Early biologic effects

Altered structure & function

Clinical disease

Susceptibility factors (e.g., genetic polymorphisms)

Effect modifiers (e.g., diet, habits, health, medications, co-exposures)
The Environmental Health Paradigm

1. Exposure
2. Internal dose
3. Biologically effective dose
4. Early biological effects
5. Altered structure and function
6. Clinical disease
Physical agent example: Chernobyl (1986)

Images: Mark Berry
Ionizing radiation

Radiation in body

Radiation: rapidly-dividing cells

Tissue damage

GI and immune disease

Radiation sickness

Image source: nature.com
Toxicant example: London Fog (1952)

Image source: Central press/Hulton archive/Getty Images
Video source: The Guardian  
https://youtu.be/ngk6euJRxpo
Toxicant example: London Fog (1952)

The graph illustrates the pollution concentration (mg/m³) and deaths per day during December 1952. The graph shows a significant increase in pollution and deaths, peaking during the middle of the month. The graph indicates a 10,000 excess deaths attributed to the increased levels of pollution, specifically smoke and sulfur dioxide.
PM$_{2.5}$ (smoke) → Respired PM$_{2.5}$ → PM$_{2.5}$ in alveoli → Cellular inflammation → Airway changes → Respiratory symptoms

*Image source: lung.org*
Infectious agent example: Methicillin-resistant *Staphylococcus aureus* (MRSA)

One of the most commonly identified antibiotic-resistant pathogens globally

– In U.S. 2003-04 NHANES estimate for nasal colonization rates:
  – *S. aureus* colonization: 28% of population
  – MRSA: 1.5% of population

Colonize nares (nasal cavity) and skin sites

Image source: Microbiology Online
MRSA infection
Image source: Mayo Clinic

[S. aureus in environment]

[S. aureus colonization]

[S. aureus at injury site]

Infected skin cells

Formation of abscess

Skin infection
Sources of exposures

Source

Environmental media

Exposure
Exposure occurs through Environmental Media:

- Air
- Water
- Food
- Soil / Dust

and may be mediated via the Built Environment.
How are we exposed to our environments?

Air
- Lungs
- GI tract

Food
- Lungs
- GI tract

Water
- GI tract
- Skin

Animals
- Skin

Psychosocial/Cultural
- Sensory

Soil/Dust
- Skin

Adapted from Moeller, DW 1997
What are different kinds of exposures?

• **Physical**, e.g. noise, radiation
• **Chemical**, e.g. pesticides, volatile organic compounds (VOCs)
• **Biological**, e.g. microbes, allergens

Also:

• Ergonomic
• Safety
• Social
• Psychological
How are we exposed to different agents?

• **Inhalation** (breathing)
• **Absorption** (skin contact)
• **Ingestion** (eating)
• **Injection**
How do we measure exposures?

- **Duration**: how long does the exposure last?
- **Concentration**: how high was the exposure?
- **Frequency**: if the exposure recurs, how often does this happen?

**Workers:**
Occupational cohorts may be exposed at high concentrations.

"Radium Girls" at Ingersoll Factory
(Daily Herald Archive/SSPL/Getty Images)
Biomarkers: Measurement of Exposure

Sexton et al., *EHP*, 1995
Susceptibility and other factors

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Susceptibility factors
(e.g., genetic polymorphisms)

Effect modifiers
(e.g., diet, habits, health, medications, co-exposures)
Susceptible subpopulations

• Groups of people at particular risk

• Biological (host-related) factors
  – Age
  – Sex
  – Race/Ethnicity
  – Genetic factors

• Extrinsic (exposure-related) factors
  – Nutritional status
  – Geographic location
  – Socioeconomic status
  – Comorbidities (other diseases)
Behavior & co-exposures

• Activity level
  – Obesity
  – Cardiovascular (CV) and respiratory fitness
  – Physical activity and tidal volume (lungs)

• Lifestyle (e.g. urban/suburban/rural)

• Concurrent exposures
  – Smoking: respiratory irritation, carcinogens, CV

• Occupation
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• Occupation
Healthy Worker Effect

• Workers are typically less susceptible to disease than the general population
• Sicker people are less likely to be able to work
• *Selection bias*
Exposure

Interventions to reduce exposure

Clinical disease
Protective behaviors

• Physical barriers to exposure
  – Personal Protective Equipment (PPE), e.g. masks, gloves

• Personal exposure reduction or avoidance
  – Vaccination, social distancing

• Source exposure reduction or elimination
  – Mosquito control
  – Disease eradication

Image source: health.mil
National Institute of Occupational Safety and Health

Hierarchy of Controls

- Elimination: Physically remove the hazard
- Substitution: Replace the hazard
- Engineering Controls: Isolate people from the hazard
- Administrative Controls: Change the way people work
- PPE: Protect the worker with Personal Protective Equipment

Source: NIOSH
Applying the Hierarchy of Controls to COVID-19

Applying the Hierarchy of Controls for COVID-19

Elimination
Social Isolation

Substitution
Not applicable

Engineering Controls
Ventilation, physical barriers

Administrative Controls
Work from home, stagger schedules, hand hygiene

PPE
Masks, respirators, gloves

Adapted from NIOSH

Adapted by Drs. Kirsten Koehler & Ana Rule
## Regulation and Source Reduction (U.S. example)

<table>
<thead>
<tr>
<th>U.S. Agency</th>
<th>Name</th>
<th>Type</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>EPA:</td>
<td>MCL: Maximum Contaminant Level</td>
<td>Legally-enforceable limit</td>
<td>Maximum concentration of contaminant allowed in drinking water</td>
</tr>
<tr>
<td>EPA:</td>
<td>NAAQS: National Ambient Air Quality Standards</td>
<td>Legally-enforceable limit</td>
<td>Maximum concentration of contaminant allowed in ambient air</td>
</tr>
<tr>
<td>ATSDR (CDC):</td>
<td>MRLs: Minimal Risk Levels</td>
<td>Advisory Levels</td>
<td>Amount of a chemical exposure not expected to cause non-cancer health effects</td>
</tr>
</tbody>
</table>

Adapted from the Missouri Department of Health
EPA NAAQS data

Figure 1. Changes in Concentrations of Criteria Pollutants, 1990–2015. Data are from the EPA (https://gispub.epa.gov/air/trendsreport/2016/). NAAQS denotes National Ambient Air Quality Standards.