Earth Materials and Human Health
The Green Revolution

Green agriculture requires

- Fertilizer (nitrogen, potassium, and phosphorous)
- Pesticides
- Irrigation
Nutrients essential for human health
Decreasing Food-borne Minerals (vs) Increasing Mineral Deficiency Diseases

USDA – CDC – NCHS – AHA – NHNES
Percent of Samples Testing Less Than 1.0 ppm DTPA Equivalent Zn in 2015

- No data available
- 1-19% of soil samples report zinc deficiencies
- 20-34% of soil samples report zinc deficiencies
- 35-50% of soil samples report zinc deficiencies
- 51-65% of soil samples report zinc deficiencies
- 66% or more of soil samples report zinc deficiencies

*Only states with 2,000 samples or more are shown on this map

Zinc deficiency

Brain
- Decreased nerve conduction
- Neuropsychiatric disorders
- Neurosensory disorders
- Mental lethargy

Gastrointestinal tract
- Skin lesions
- Decreased wound healing
- Acrodermatitis

Reproductive system
- Infertility
- Retarded genital development
- Hypogonadism

Other symptoms
- Growth retardation
- Immune dysfunction and infection

Areas of most significant overlap
- Zinc Deficiency in Soils
  - High
  - Medium
- Zinc Deficiency in Humans
  - High
  - Medium

Zinc excess

Brain
- Lethargy
- Focal neuronal deficits

Respiratory tract
- Respiratory disorder after inhalation of zinc smoke
- Metal fume fever

Gastrointestinal tract
- Nausea/vomiting
- Epigastric pain
- Diarrhea

Prostate
- Elevated risk of prostate cancer

Systemic symptoms
- Copper deficiency and sequelae
- Altered lymphocyte function

Immune system
- T and B cell function
- Antibody production

Skin
- Wound healing
- Regeneration
- Hair growth

Sensorium
- Night vision
- Vitamin A
- Taste, olfaction
- Inner ear function

Immune system
- Zinc signaling

Hormone metabolism
- Receptor function
- Insulin storage and secretion

Lipid metabolism
- Prostaglandin synthesis
- Sexual functioning/spermatogenesis

Cell membrane/cell nucleus
- Protection against oxidative stress
- DNA, RNA synthesis and repair
- Zinc finger proteins
A Stylized Map** of Selenium Distribution in the U.S.

Selenium Soil Levels
- Adequate
- Variable
- Low

** adapted from [www.ansci.cornell.edu/plants/toxicagents/selenium/map1.html]

Acanthite

SELENIUM Health Benefits
- Prevention of dandruff
- Eyes and vision
- Thyroid and Immune system
- Heart, cardiovascular system
- Skin elasticity
- Sperm production, quality
- "Hot flashes" during menopause

Dietary Se availability
- (μg capita⁻¹ day⁻¹)
  - 82 - 260
  - 68 - 81
  - 55 - 67
  - 46 - 54
  - 27 - 45
  - No data

Risk of dietary Se inadequacy
- (%)  
  - 91 - 100
  - 76 - 90
  - 26 - 75
  - 11 - 25
  - 0 - 10
  - No data
Countries Known to be Affected by Arsenic in their Drinking Water (2005)

Zheng Gong, MIT department of Civil and Environmental Engineering, August 2005

Over 30 countries in the world is affected by arsenic in drinking water
Digit in parenthesis gives the average concentrations of each geologic body. Purple and blue colored letters indicate the releasing and fixing mechanisms of arsenic in the cycle.
Arsenic-containing minerals

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>Arsenopyrite</td>
<td>FeAsS</td>
</tr>
<tr>
<td>Tennantite</td>
<td>Cu$_6$(Cu$_4$X$_2$)As$<em>4$S$</em>{12}$</td>
</tr>
<tr>
<td>Scorodite</td>
<td>Fe$^{3+}$AsO$_4$·H$_2$O</td>
</tr>
<tr>
<td>Realgar</td>
<td>AsS</td>
</tr>
<tr>
<td>Orpiment</td>
<td>As$_2$S$_3$</td>
</tr>
<tr>
<td>Löllingite</td>
<td>FeAs$_2$</td>
</tr>
</tbody>
</table>
Arsenic
Percent Probability of Exceeding the Public Drinking Water Standard of 10 Micrograms per liter (10 PPB)

- < 1.0%
- 1.0% to 4.0%
- 5.0% to 10.0%
- 10.0% to 25.0%

Source: Massachusetts Department of Environmental Protection
T&G Staff/STACEY ARSENAULT
Primary Minerals → Secondary Minerals

**O₂, H₂O**

- **Pyrite**
  - FeS₂
  - < 0.1 wt % As

- **Arsenian pyrite**
  - Fe(S,As)₂
  - 0.1 - 6 wt % As

- **Arsenopyrite**
  - FeAsS
  - 46 wt % As

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**Goethite** FeO(OH)

**Ferrihydrite** 5Fe₂O₃·9H₂O
- < 1 wt % As

**Jarsosite** KFe₃(SO₄)₂(OH)₆
- ~1 wt % As

**Copiapite** Fe²⁺₄Fe³⁺₄(SO₄)₆(OH)₂·20H₂O
- ~1 wt % As

**Goethite** FeO(OH)
**Ferrihydrite** 5Fe₂O₃·9H₂O
- 1 - 6 wt % As

**Goethite** FeO(OH)
**Ferrihydrite** 5Fe₂O₃·9H₂O
- 6 - 18 wt % As

**Hydrous ferric arsenate (HFA)**

[Fe(OH)₃]₃[FeAsO₄]₀·nH₂O
- 18 - 30 wt % As

**Scorodite**
- FeAsO₄·2H₂O
- 32 wt % As

**Arseniosiderite**
- Ca₂Fe₃(AsO₄)₃(OH)₅·3H₂O
- 29 wt % As

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**Increasing arsenic**
$2\text{FeAsS} + 11\text{O}_2 + 3\text{H}_2\text{O} \rightarrow 2\text{Fe}^{2+} + 2\text{SO}_4^{2-} + 2\text{As(OH)}_3$  
$2\text{Fe}^{2+} + 1/2\text{O}_2 + (2n+3)\text{H}_2\text{O} \rightarrow 2\text{FeOOH} \cdot n\text{H}_2\text{O} + 4\text{H}^+$  
$\text{As(OH)}_3 + 1/2\text{O}_2 \rightarrow \text{H}_2\text{AsO}_4^{-} + \text{H}^+$  
$\text{H}_2\text{AsO}_4^{-} + \text{FeOOH} \cdot n\text{H}_2\text{O} \rightarrow \text{FeOOH} \cdot n\text{H}_2\text{O} \cdot \text{H}_2\text{AsO}_4^{-}$
Fluoride in Groundwater
Fluoride and health

The optimum concentrations of fluoride in drinking water lie within a relatively narrow range.

Fluoride has long been found to have a beneficial effect on dental health, although when present in drinking water at concentrations much above the WHO guideline value (and national drinking water limit for most countries) of 1.5 mg/L, long term use can result in development of dental fluorosis or at its worst, crippling skeletal fluorosis.

The effects on health depend on a number of factors including dose from other sources of fluoride (toothpastes, food), age, gender and general health status.

High-fluoride groundwaters tend to be found in association with:

- crystalline rocks containing fluorine-rich minerals, especially granites and volcanic rocks
- shallow aquifers in arid areas experiencing strong evaporation
- sedimentary aquifers undergoing ion exchange
- inputs of geothermal water
High-fluoride groundwater, derived from combinations of reaction with young volcanic rocks, geothermal inputs and evaporation, occurs alongside alkaline lakes (pH>8) with, in some cases, concentrations of dissolved fluoride up to 300 mg/L.

The association of high-fluoride groundwaters with granites and acidic volcanic rocks occurs because of the relative abundance in these rocks of high-fluoride minerals such as biotite, amphibole, apatite and fluorite.
Asbestos is a set of six naturally occurring silicate minerals, which all have in common their eponymous asbestiform habit: i.e. long (roughly 1:20 aspect ratio), thin fibrous crystals, with each visible fiber composed of millions of microscopic "fibrils" that can be released by abrasion and other processes.[2] They are commonly known by their colors, as blue asbestos, brown asbestos, white asbestos, and green asbestos.

**Common Asbestos Minerals**

<table>
<thead>
<tr>
<th>Mineral</th>
<th>Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>chrysotile</td>
<td>(Mg,Fe)$_3$Si$_2$O$_5$(OH)$_4$</td>
</tr>
<tr>
<td>Amphiboles</td>
<td></td>
</tr>
<tr>
<td>tremolite</td>
<td>Ca$_2$(Mg,Fe)$_5$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
<tr>
<td>actinolite</td>
<td>Ca$_2$(Mg,Fe)$_5$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
<tr>
<td>cummingtonite</td>
<td>(Mg,Fe$^{2+}$)$_7$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
<tr>
<td>grunerite</td>
<td>(Mg,Fe$^{2+}$)$_7$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
<tr>
<td>riebeckite</td>
<td>Na$_2$(Mg,Fe$^{2+}$)$_3$Fe$^{3+}_2$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
<tr>
<td>anthophyllite</td>
<td>(Mg,Fe$^{2+}$)$_7$Si$<em>8$O$</em>{22}$(OH)$_2$</td>
</tr>
</tbody>
</table>

**Exposure** → **Dose** → **Effect**

- Critical Cells at risk
- Lung cancer
- Mesothelioma
- Fibrosis

- Fiber dimension
- Breathing pattern
- Bronchial anatomy
- Clearance
- Dissolution

- Gender
- Inflammation
- Age
- Cigarette Smoke
- Environmental agents
Differences between types of asbestos

### Asbestos: Types

<table>
<thead>
<tr>
<th>Serpentine</th>
<th>Amphibole</th>
</tr>
</thead>
<tbody>
<tr>
<td>(93% of commercial use)</td>
<td>Actinolite, Amosite, Anthophyllite, Crocidolite, Richterite, Tremolite</td>
</tr>
<tr>
<td>Chrysotile</td>
<td></td>
</tr>
</tbody>
</table>

- **Serpentine**: characteristically soft, white, and flexible. Commonly used in commercial applications due to its flexibility and biocompatibility.
- **Amphibole**: more rigid and harder than Serpentine. It is less common in commercial use but known for its durability and heat resistance.

**Chemical Composition**

- **Mg** and **Si** form the basis of asbestos minerals.

**Structural Diagrams**

1. **Mg** and **Si** chains forming the backbone of asbestos structures.
2. The rolled-up appearance in diagrams represents the unique fiber-like structure.

**Visual Images**

- Images of asbestos minerals, showing the fiber-like characteristics and varying degrees of complexity in their structure.
Health effects of asbestos exposure

- Bronchogenic carcinoma
- Pleural Mesothelioma
- Asbestosis
- Pleural Plaque

Asbestosis, Healthy Lungs, Mesothelioma
Smoking and Asbestos

Lung Cancer Risks

- No Exposure: 70 per 100,000 lung cancer deaths in general population
- Asbestos: 5x higher risk than general population
- Smoking: 10x higher risk
- Asbestos + Smoking: 50x to 90x higher risk
Silicosis