Earth Materials and Human Health

The Green Revolution

Green agriculture requires

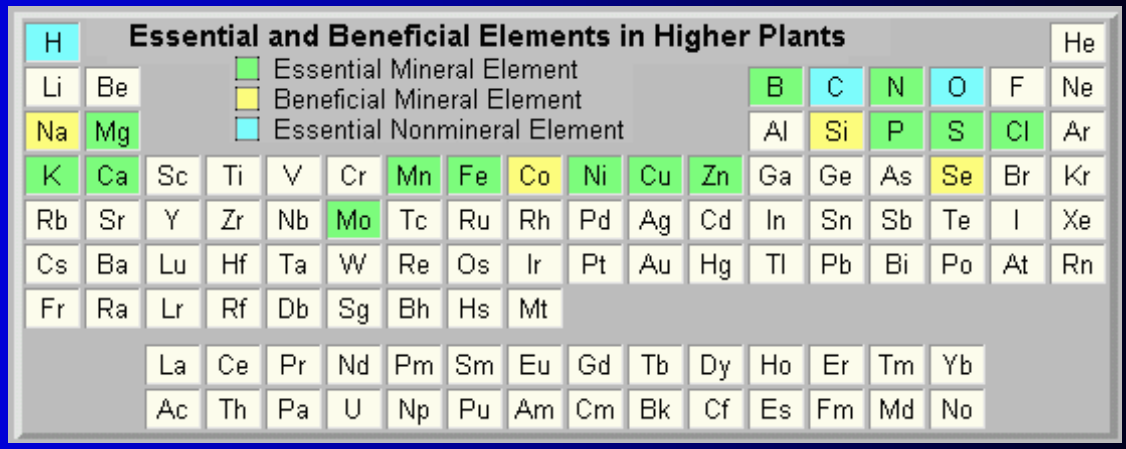
- Fertilizer (nitrogen, potassium, and phosphorous
- Pesticides
- Irrigation

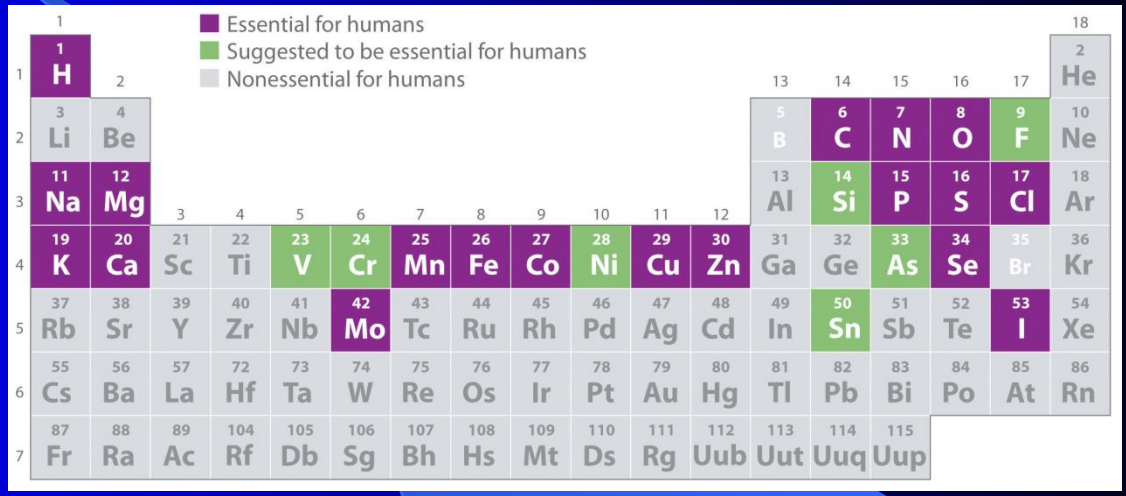
Nutrients essential for human health

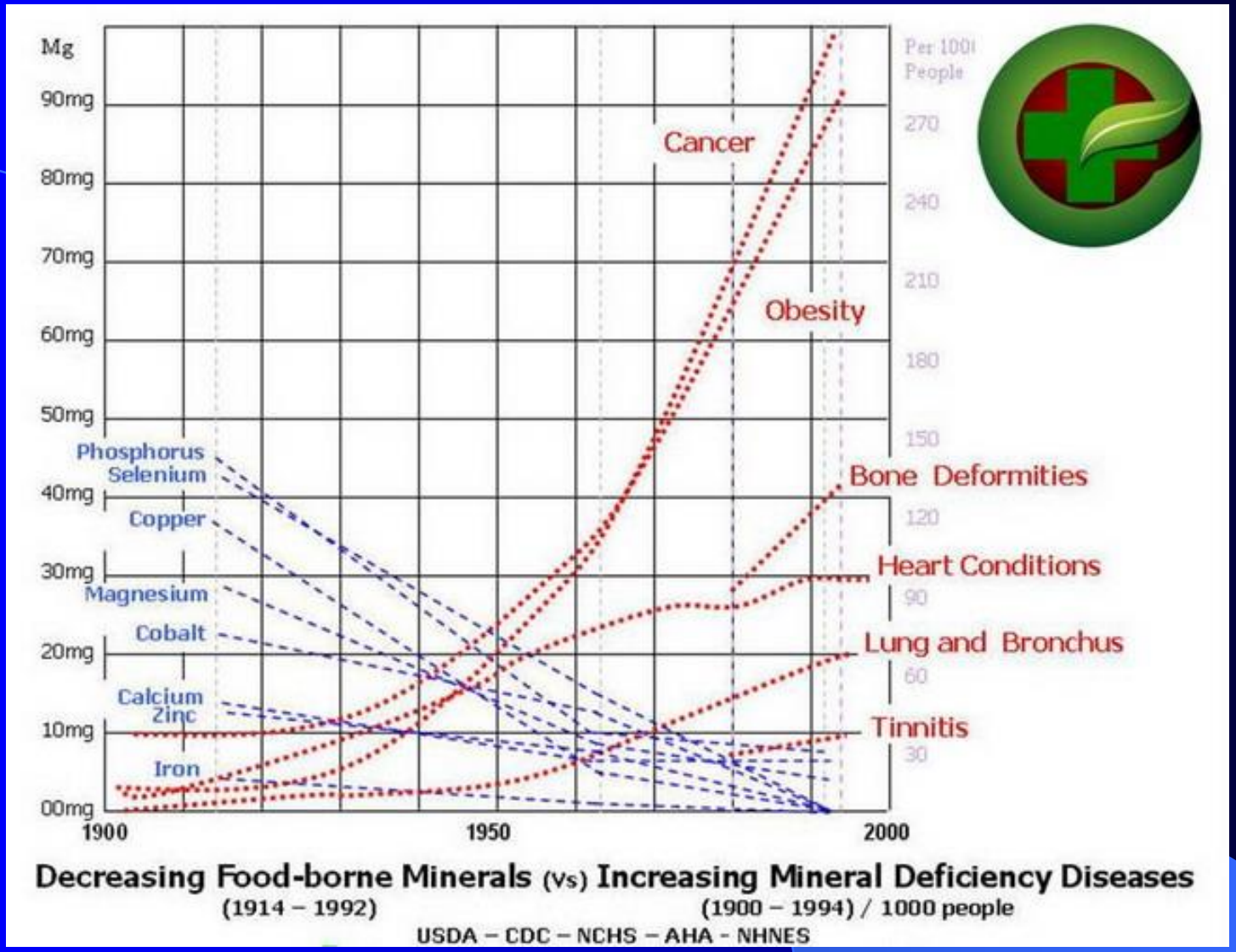
NUTRITIONAL INFORMATION

	Per Tablet	% RDA
Vitamin A	725 µg RE	91
Vitamin D	4.5 µg	90
Vitamin E	10 mg α-TE	83
Vitamin C	55 mg	69
Vitamin B1	1.4 mg	127
Vitamin B2	1.6 mg	114
Niacin	18 mg NE	113
Vitamin B6	2 mg	143
Folic Acid	200 µg	100
Vitamin B12	1 µg	40
Biotin	150 µg	300
Pantothenic Acid	6 mg	100
Vitamin K	20 µg	27
Calcium	200 mg	25
Phosphorus	145 mg	21
Iron	14 mg	100
Magnesium	100 mg	27
Zinc	15 mg	150
Iodine	150 µg	100
Copper	1000 µg	100
Manganese	1 mg	50
Chromium	25 µg	63
Selenium	50 µg	91

RDA = Recommended Daily Allowance
α-TE = Alpha Tocopherol Equivalent
NE = Niacin Equivalent
RE = Retinol Equivalent



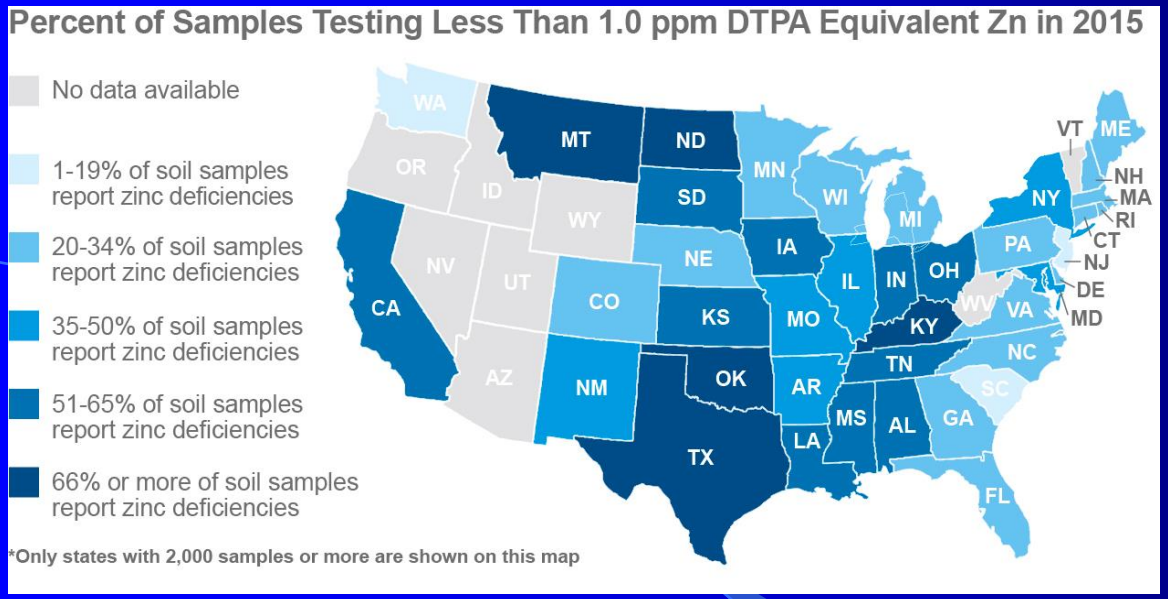


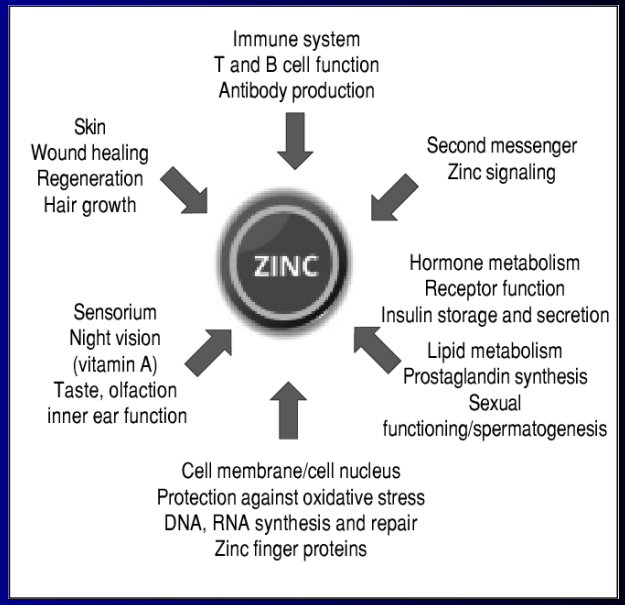


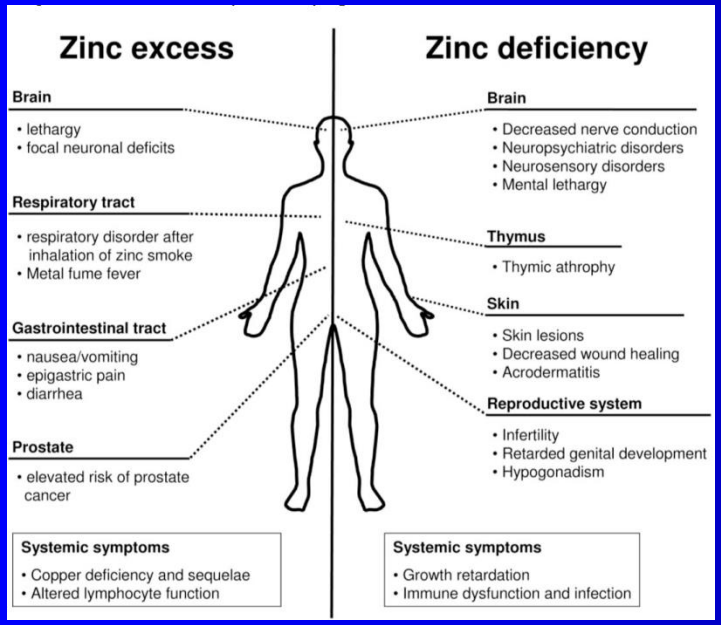
Decreasing Food-borne Minerals (vs) Increasing Mineral Deficiency Diseases

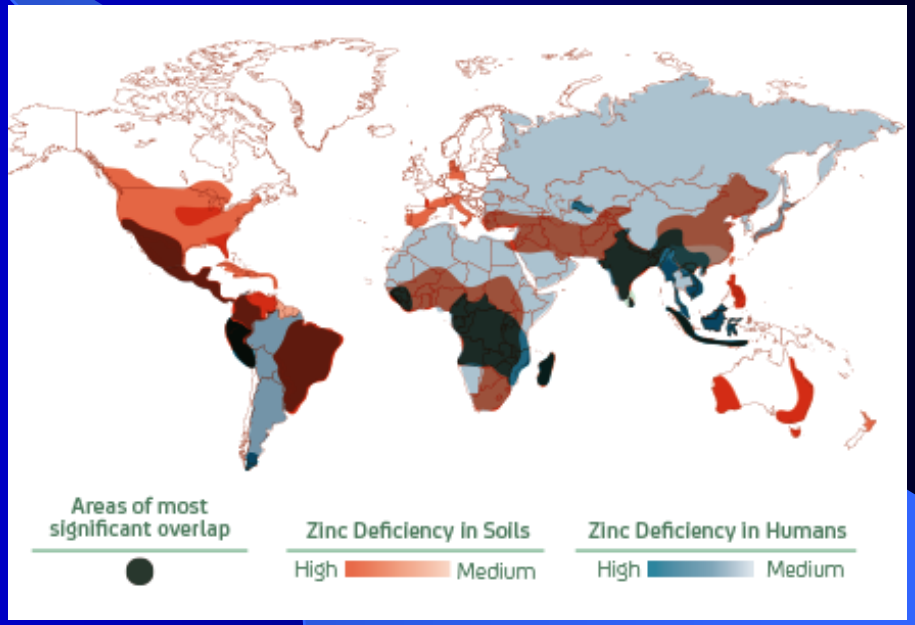
(1914 – 1992) (1900 – 1994) / 1000 people

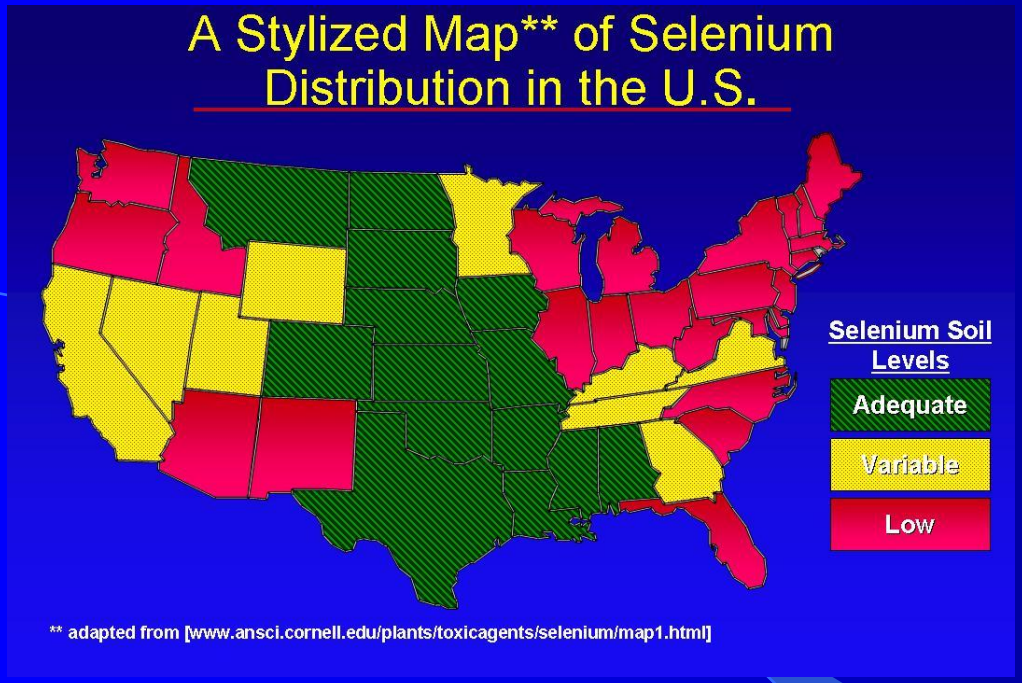
USDA – CDC – NCHS – AHA - NHNES

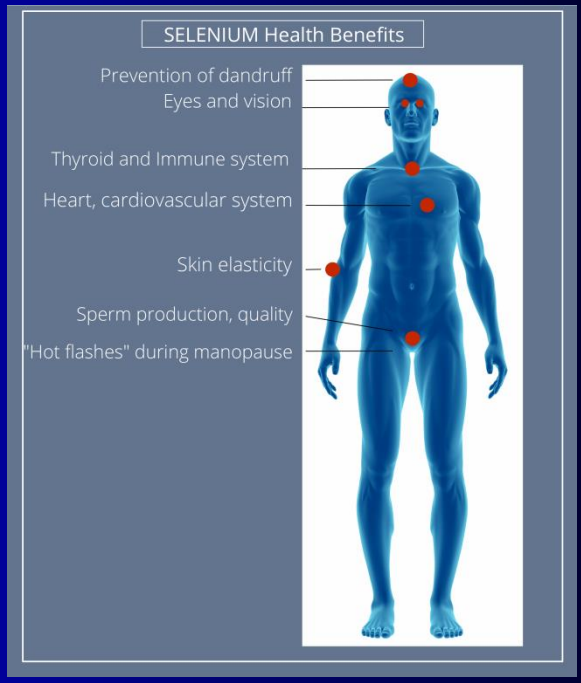

Percent of Samples Testing Less Than 1.0 ppm DTPA Equivalent Zn in 2015
No data available
1-19% of soil samples report zinc deficiencies
20-34% of soil samples report zinc deficiencies
35-50% of soil samples report zinc deficiencies
51-65% of soil samples report zinc deficiencies
66% or more of soil samples report zinc deficiencies
*Only states with 2,000 samples or more are shown on this map
WA
OR
CA
ID
NV
MT
WY
UT
AZ
CO
NM
ND
SD
NE
KS
OK
TX
MN
IA
MO
AR
LA
WI
IL
MS
MI
IN
KY
TN
AL
OH
WV
GA
FL
SC
NC
VA
PA
NY
VT
ME
NH
MA
RI
CT
NJ
DE
MD


Immune system
T and B cell function
Antibody production
Skin
Wound healing
Regeneration
Hair growth
Second messenger
Zinc signaling
ZINC
Hormone metabolism
Receptor function
Insulin storage and secretion
Sensorium
Night vision
(vitamin A)
Taste, olfaction
inner ear function
Lipid metabolism
Prostaglandin synthesis
Sexual
functioning/spermatogenesis
Cell membrane/cell nucleus
Protection against oxidative stress
DNA, RNA synthesis and repair
Zinc finger proteins

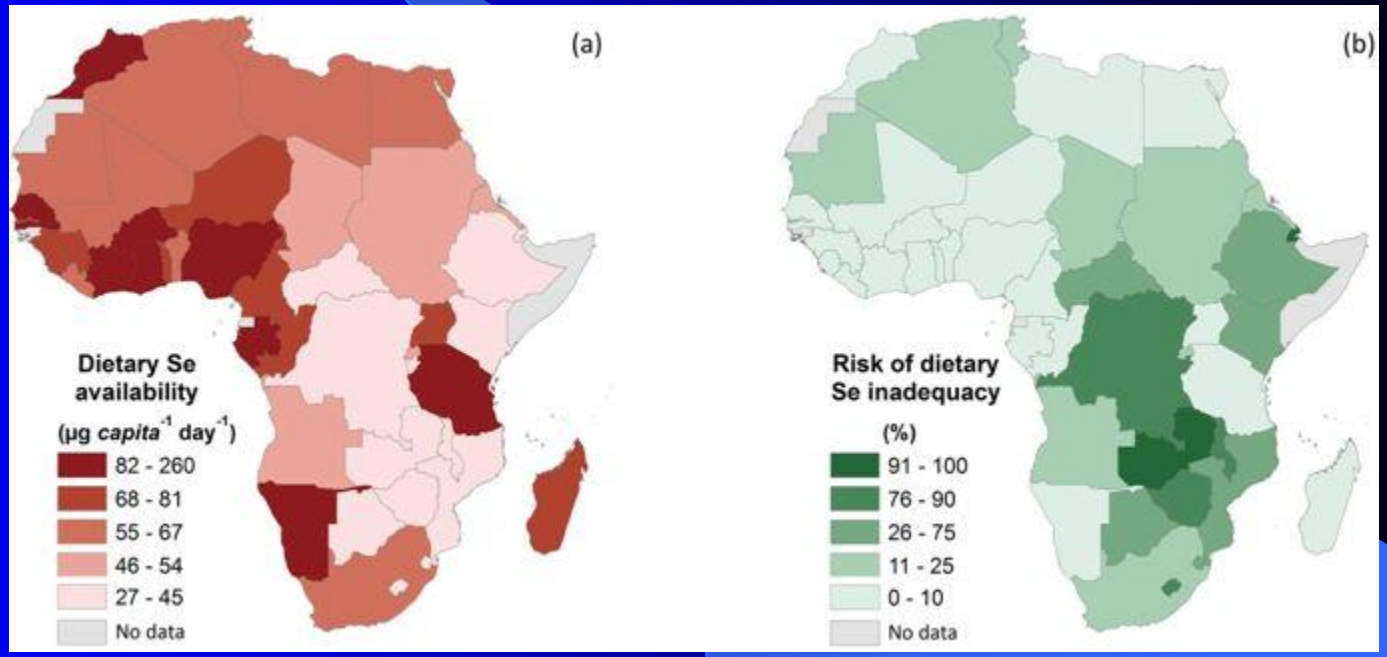

Zinc excess
Zinc deficiency
Brain
• lethargy
• focal neuronal deficits
Respiratory tract
• respiratory disorder after inhalation of zinc smoke
• Metal fume fever
Gastrointestinal tract
• nausea/vomiting
• epigastric pain
• diarrhea
Prostate
• elevated risk of prostate cancer
Systemic symptoms
• Copper deficiency and sequelae
• Altered lymphocyte function
Brain
• Decreased nerve conduction
• Neuropsychiatric disorders
• Neurosensory disorders
• Mental lethargy
Thymus
• Thymic athrophy
Skin
• Skin lesions
• Decreased wound healing
• Acrodermatitis
Reproductive system
• Infertility
• Retarded genital development
• Hypogonadism
Systemic symptoms
• Growth retardation
• Immune dysfunction and infection


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


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]

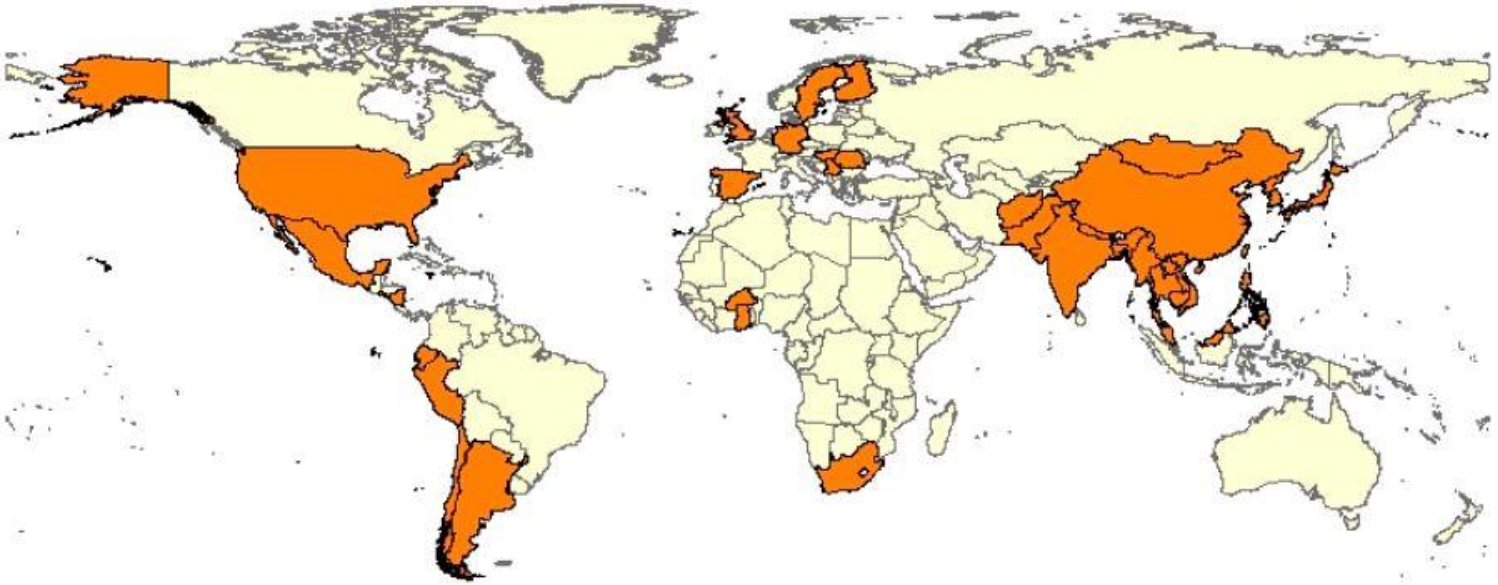

SELENIUM Health Benefits
Prevention of dandruff
Eyes and vision
Thyroid and Immune system
Heart, cardiovascular system
Skin elasticity
Sperm production, quality
"Hot flashes" during manopause

Acanthite

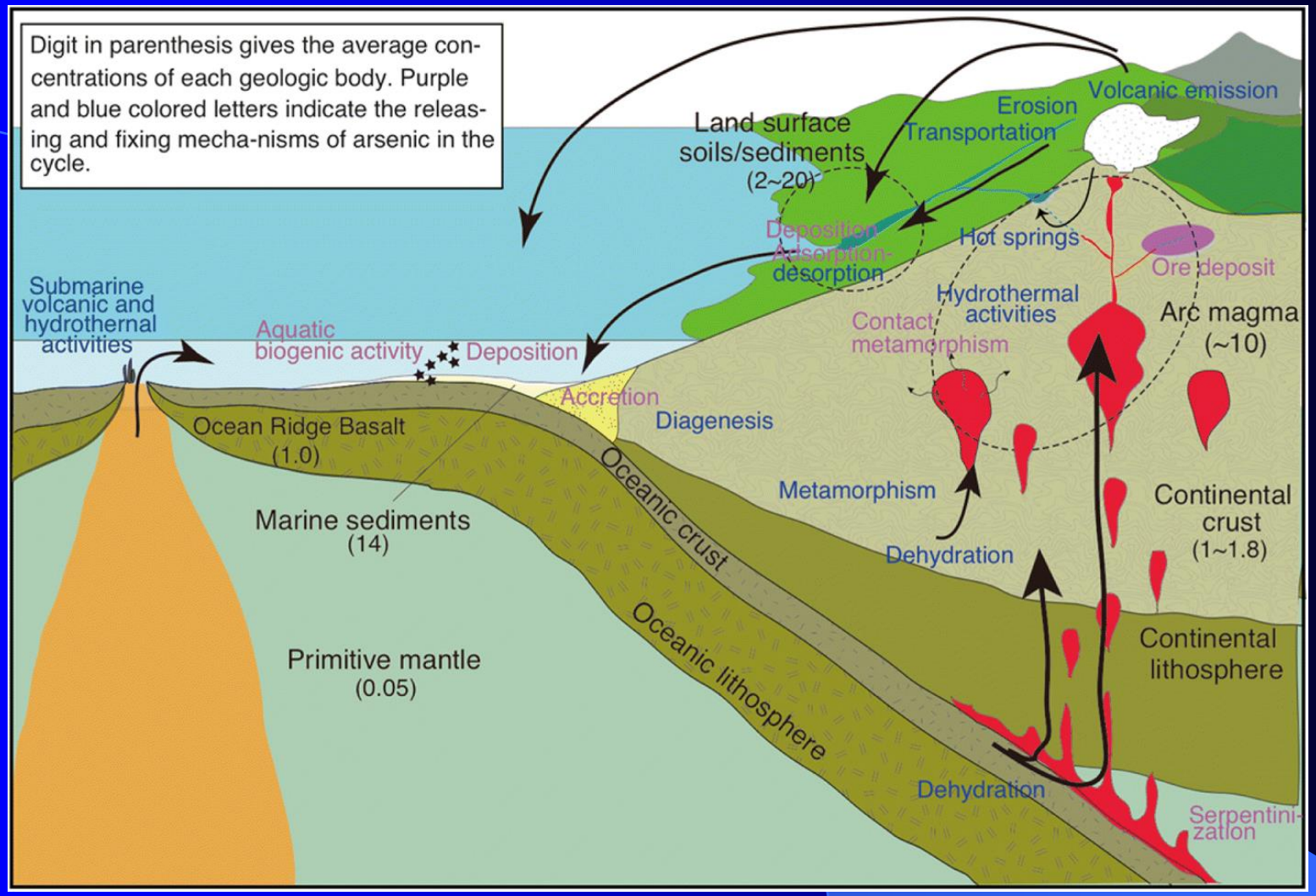

(a)
Dietary Se availability
(µg capita-1 day-1)
82 - 260
68 - 81
55 - 67
46 - 54
27 - 45
No data
(b)
Risk of dietary Se inadequacy
(%)
91 - 100
76 - 90
26 - 75
11 - 25
0 - 10
No data

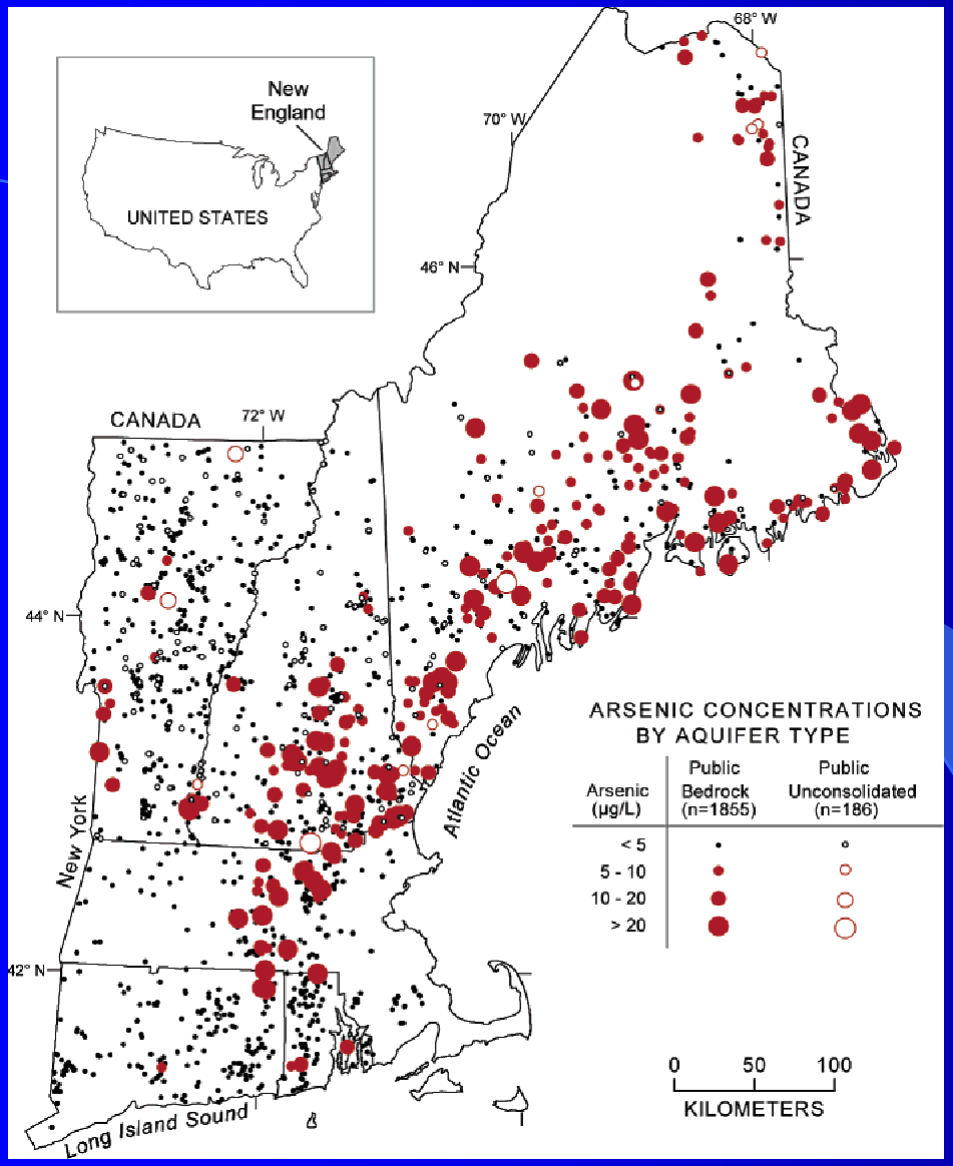
Countries Known to be Affected by Arsenic in their Drinking Water (2005)

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 mecha-nisms of arsenic in the cycle.
Land surface soils/sediments (2~20)
Erosion
Transportation
Volcanic emission
Deposition
Adsorption-desorption
Hot springs
Ore deposit
Hydrothermal activities
Contact metamorphism
Arc magma (~10)
Submarine volcanic and hydrothermal activities
Aquatic biogenic activity
Deposition
Accretion
Diagenesis
Ocean Ridge Basalt (1.0)
Oceanic crust
Metamorphism
Continental crust (1~1.8)
Marine sediments (14)
Dehydration
Continental lithosphere
Primitive mantle (0.05)
Oceanic lithosphere
Dehydration
Serpentini-zation



Arsenic-containing minerals

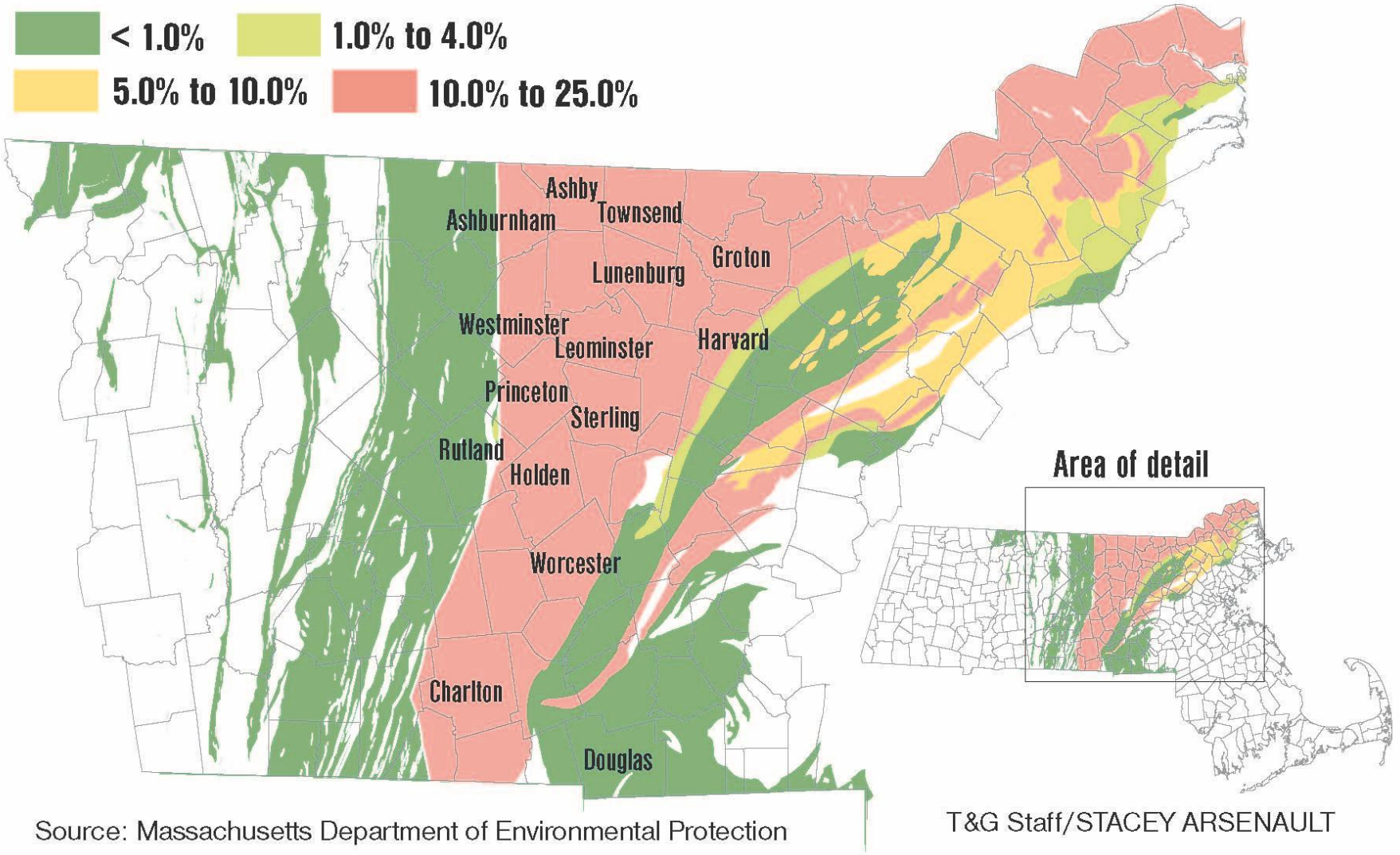
Mineral	Formula
Arsenopyrite	FeAsS
Tennantite	$Cu_6(Cu_4X_2)As_4S_{12}$
Scorodite	$Fe^{3+}AsO_4 \cdot H_2O$
Realgar	AsS
Orpiment	As_2S_3
Löllingite	$FeAs_2$

Arsenopyrite

Realgar

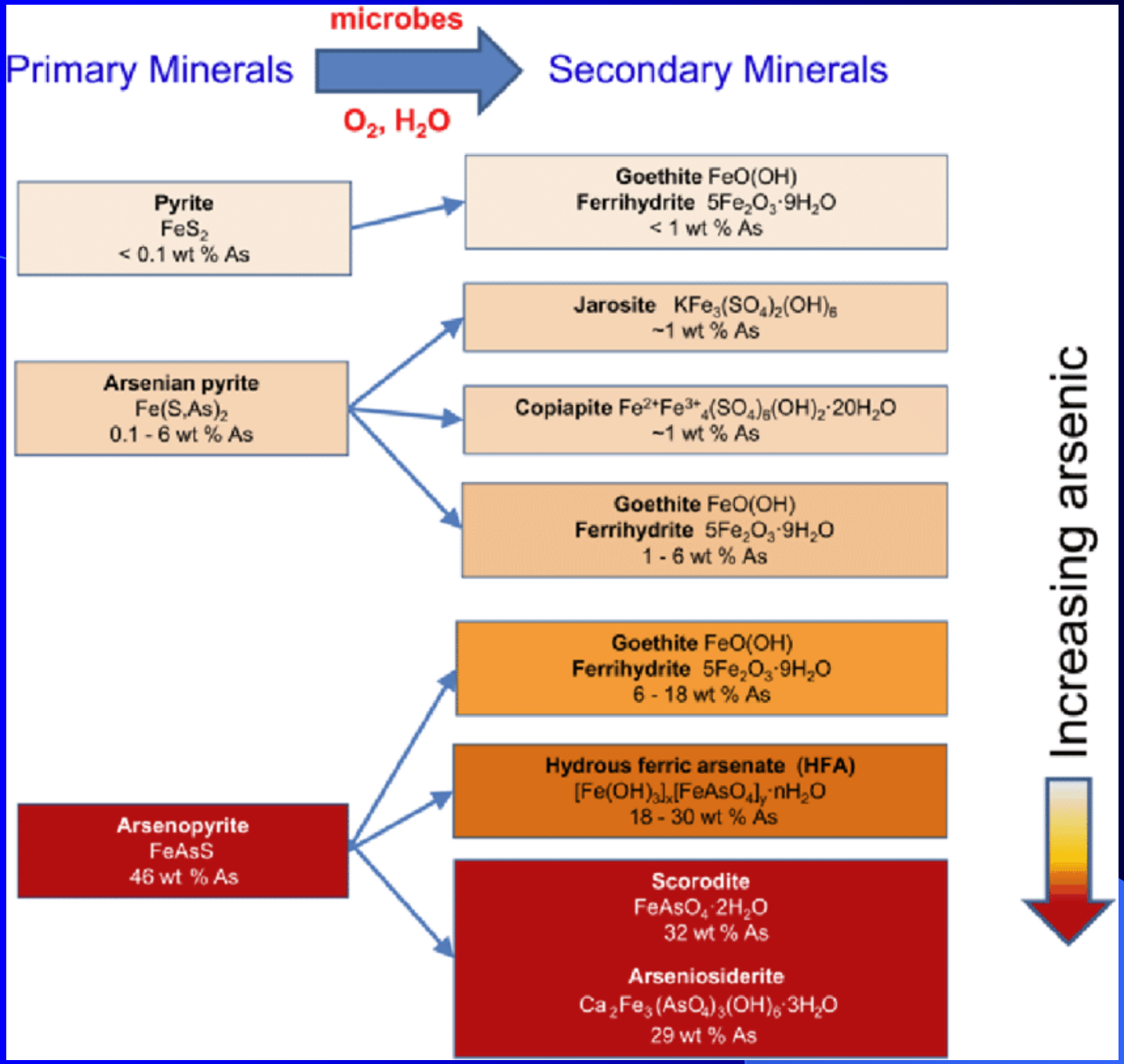
Arsenic

Percent Probability of Exceeding the Public Drinking Water Standard of 10 Micrograms per liter (10 PPB)



Source: Massachusetts Department of Environmental Protection

T&G Staff/STACEY ARSENAULT

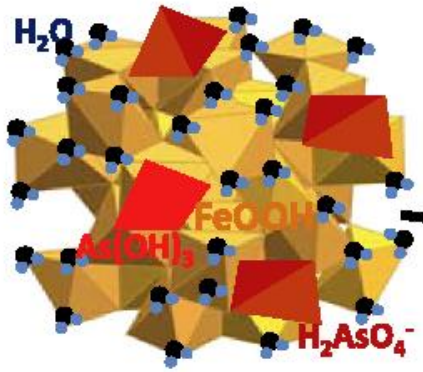

microbes
Primary Minerals
Secondary Minerals
O_2, H_2O
Pyrite
FeS_2
< 0.1 wt % As
Goethite FeO(OH)
Ferrihydrite $5Fe_2O_3 \cdot 9H_2O$
< 1 wt % As
Arsenian pyrite
$Fe(S,As)_2$
0.1 - 6 wt % As
Jarosite $KFe_3(SO_4)_2(OH)_6$
~1 wt % As
Copiapite $Fe^{2+}Fe^{3+}_4(SO_4)_6(OH)_2 \cdot 20H_2O$
~1 wt % As
Goethite FeO(OH)
Ferrihydrite $5Fe_2O_3 \cdot 9H_2O$
1 - 6 wt % As
Arsenopyrite
FeAsS
46 wt % As
Goethite FeO(OH)
Ferrihydrite $5Fe_2O_3 \cdot 9H_2O$
6 - 18 wt % As
Hydrous ferric arsenate (HFA)
$[Fe(OH)_3]_x[FeAsO_4]_y \cdot nH_2O$
18 - 30 wt % As
Scorodite
$FeAsO_4 \cdot 2H_2O$
32 wt % As
Arseniosiderite
$Ca_2Fe_3(AsO_4)_3(OH)_6 \cdot 3H_2O$
29 wt % As
Increasing arsenic

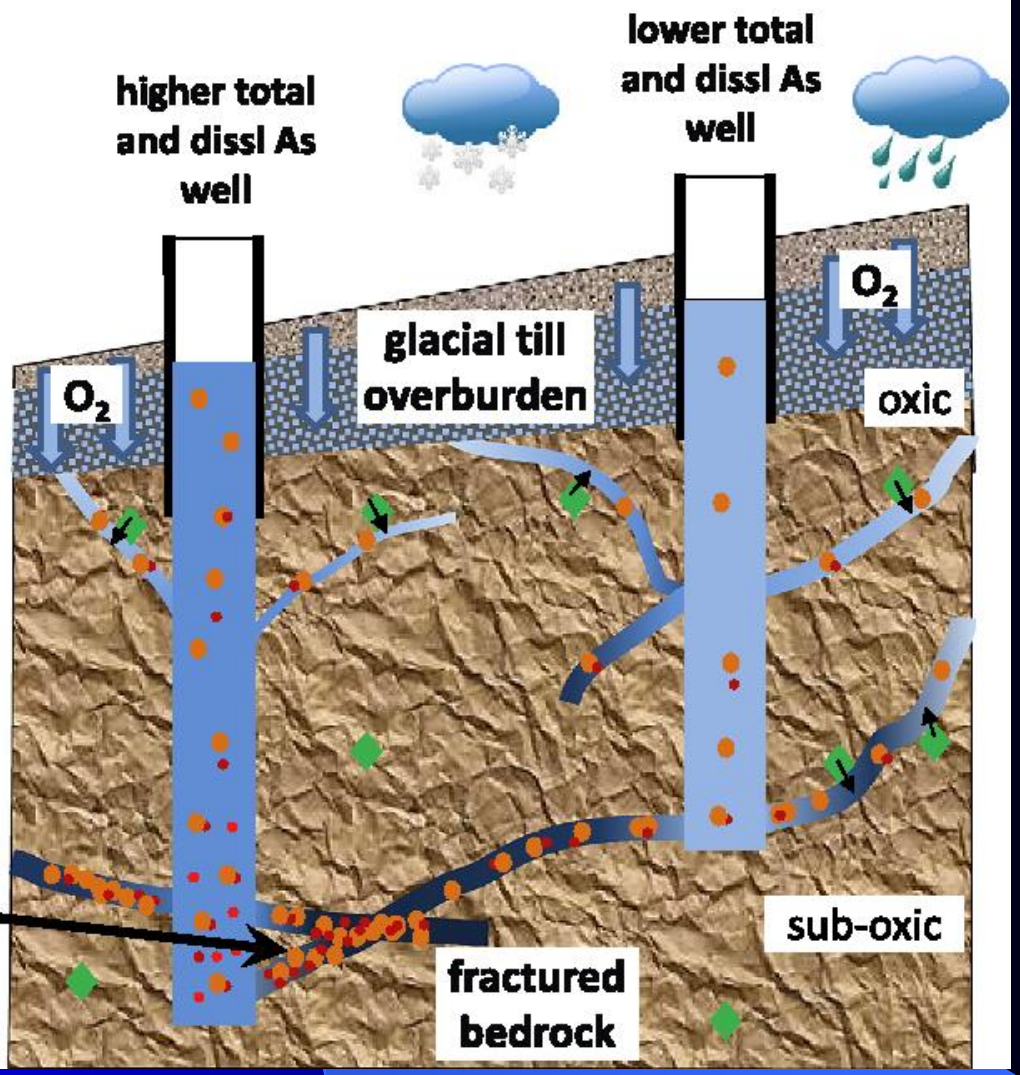
$2FeAsS + 11/2O_2 + 3H_2O \rightarrow 2Fe^{2+} + 2SO_4^{2-} + 2As(OH)_3$

$2Fe^{2+} + 1/2O_2 + (2n+3)H_2O \rightarrow 2FeOOH{\cdot}nH_2O + 4H^+$

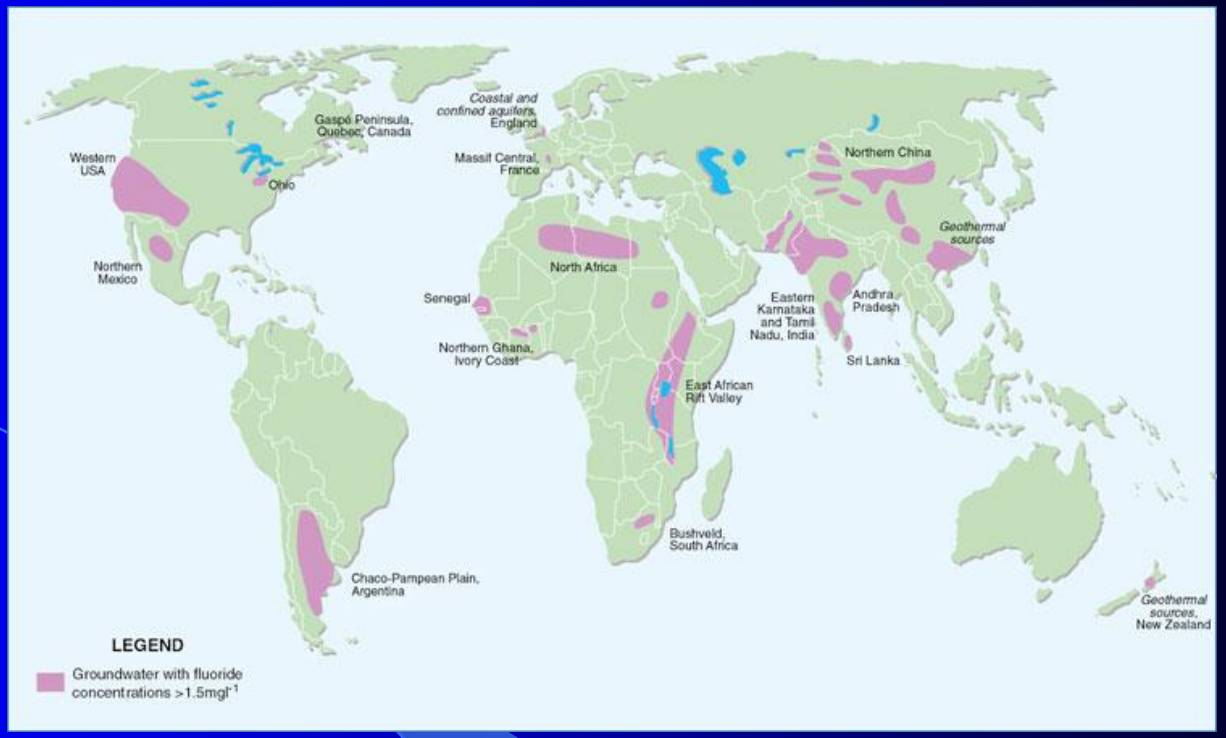
$As(OH)_3 + 1/2O_2 \cdots\cdots \rightarrow H_2AsO_4^- + H^+$

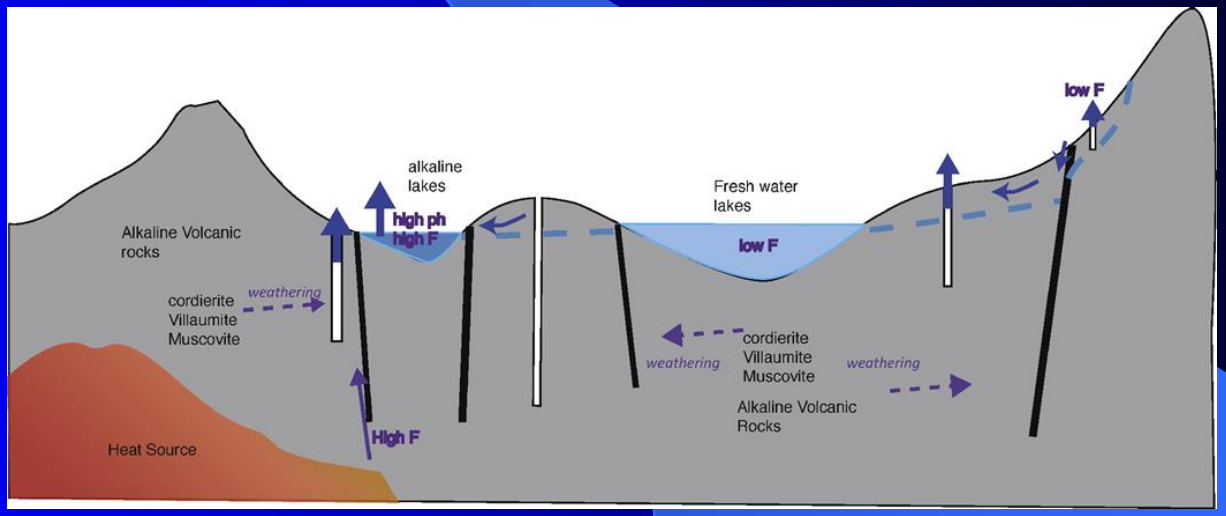
$H_2AsO_4^- + FeOOH{\cdot}nH_2O \cdots\cdots \rightarrow FeOOH{\cdot}nH_2O\text{-}\ H_2AsO_4^-$





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.

Amphibole

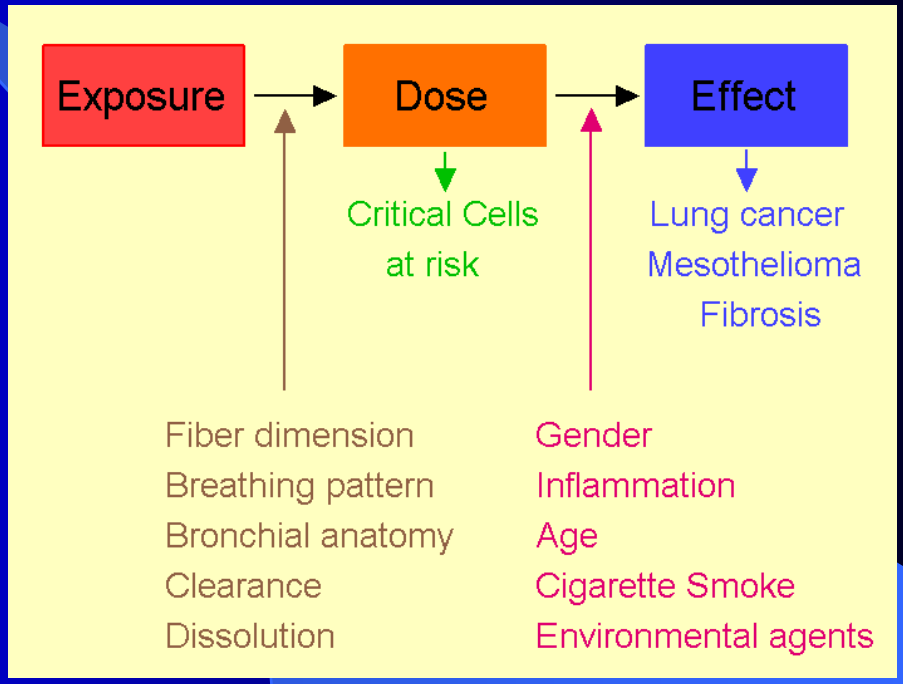
Apatite

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

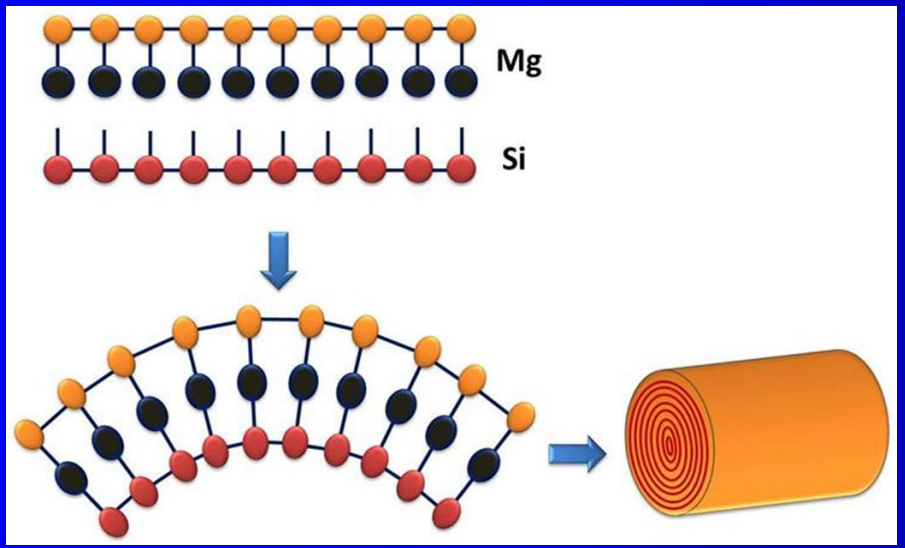
Serpentine	
chrysotile	$(Mg,Fe)_3Si_2O_5(OH)_4$
Amphiboles	
tremolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
actinolite	$Ca_2(Mg,Fe)_5Si_8O_{22}(OH)_2$
cummingtonite	$(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$
grunerite	$(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$
riebeckite	$Na_2(Mg,Fe^{2+})_3Fe^{3+}{}_2Si_8O_{22}(OH)_2$
anthophyllite	$(Mg,Fe^{2+})_7Si_8O_{22}(OH)_2$

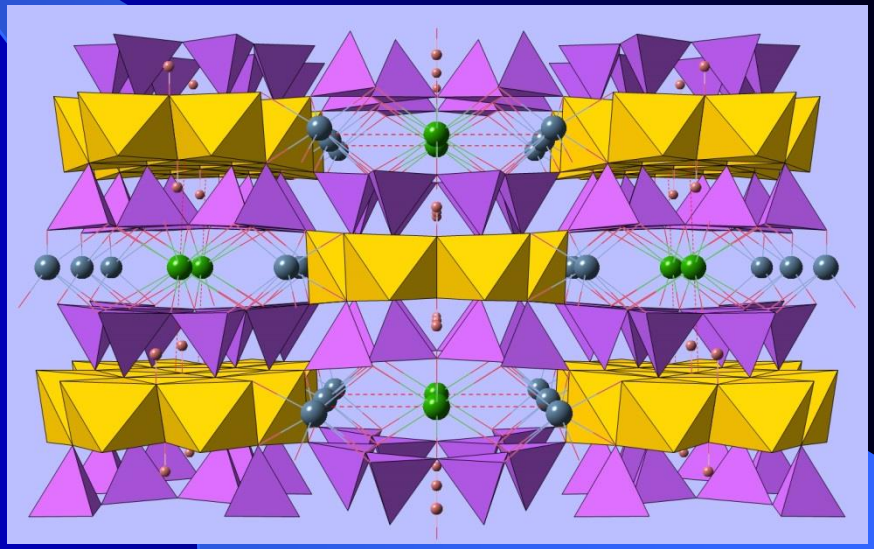


Differences between types of asbestos

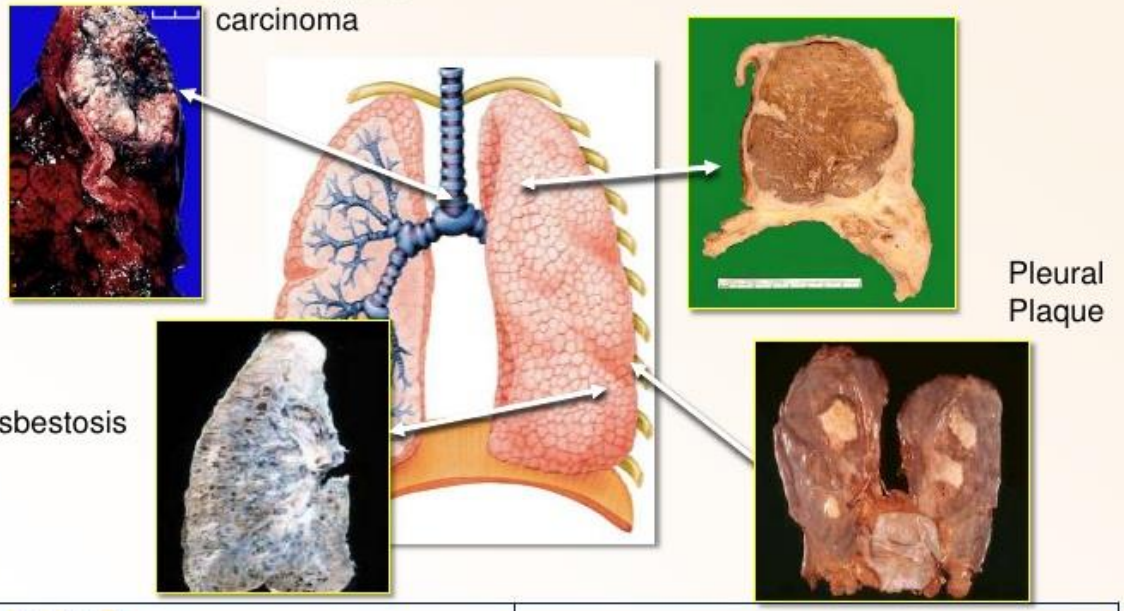
Asbestos: Types

Serpentine (93% of commercial use)	Amphibole (7% of commercial use)
Chrysotile	Actinolite, Amosite, Anthophyllite, Crocidolite, Richterite, Tremolite



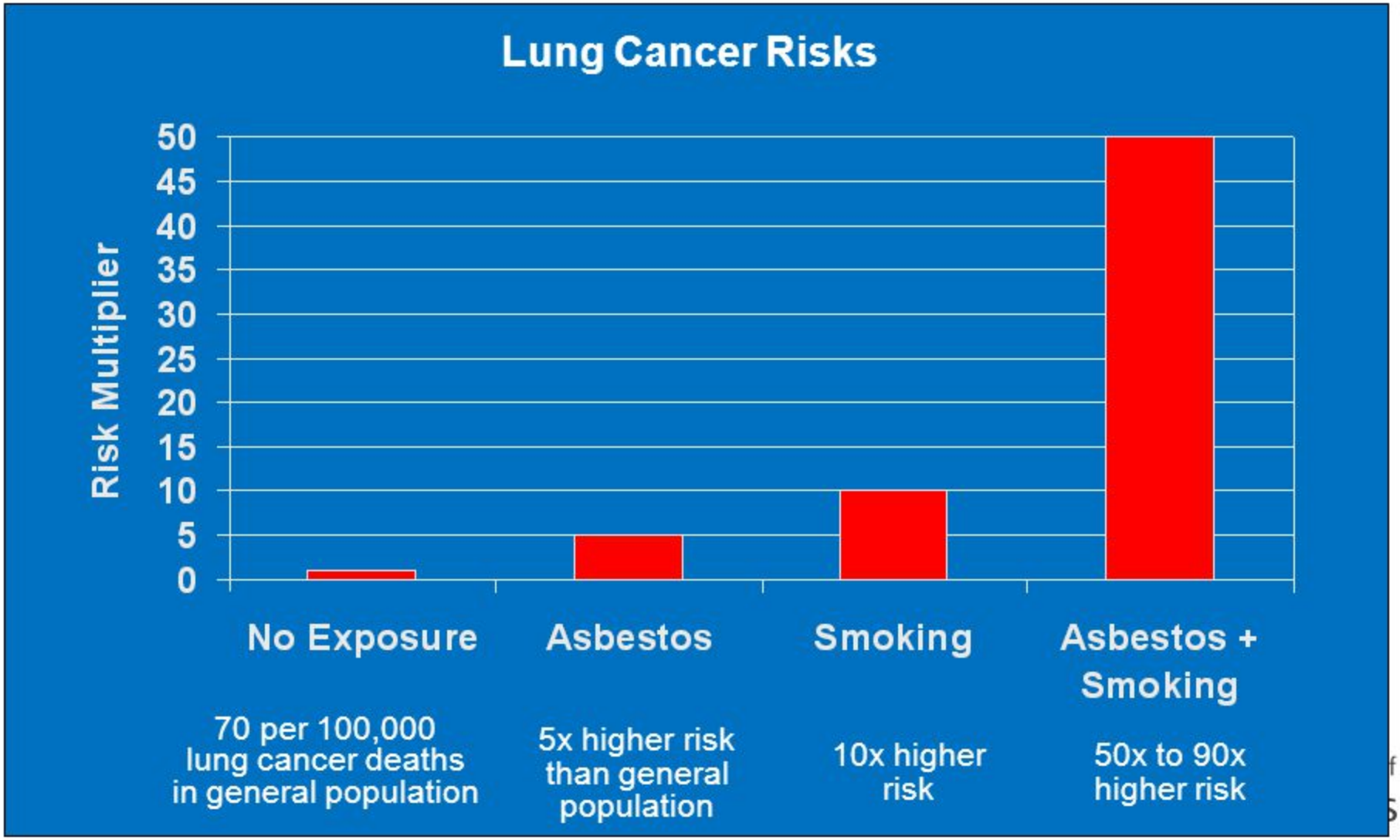


Health effects of asbestos exposure

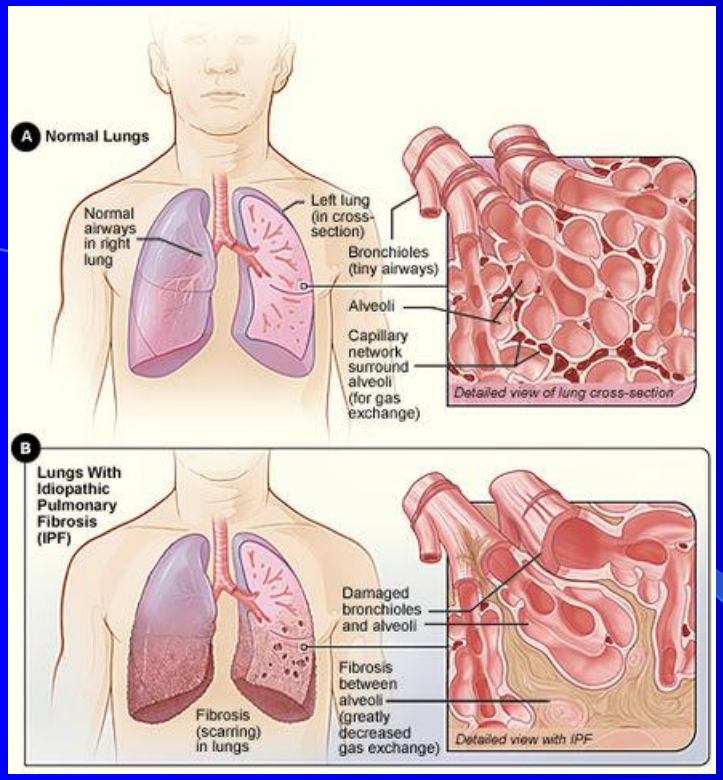


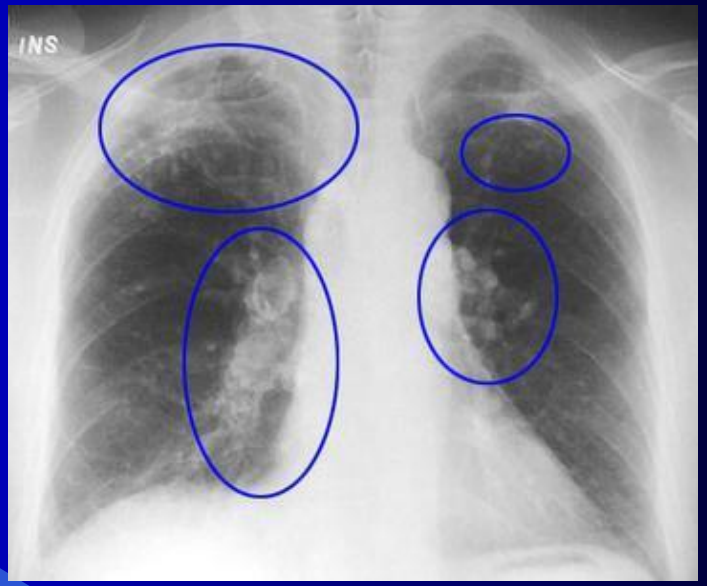
IOM

Smoking and Asbestos



Silicosis


A Normal Lungs
Normal airways in right lung
Left lung (in cross-section)
Bronchioles (tiny airways)
Alveoli
Capillary network surround alveoli (for gas exchange)
Detailed view of lung cross-section
B
Lungs With Idiopathic Pulmonary Fibrosis (IPF)
Damaged bronchioles and alveoli
Fibrosis between alveoli (greatly decreased gas exchange)
Fibrosis (scarring) in lungs
Detailed view with IPF


INS

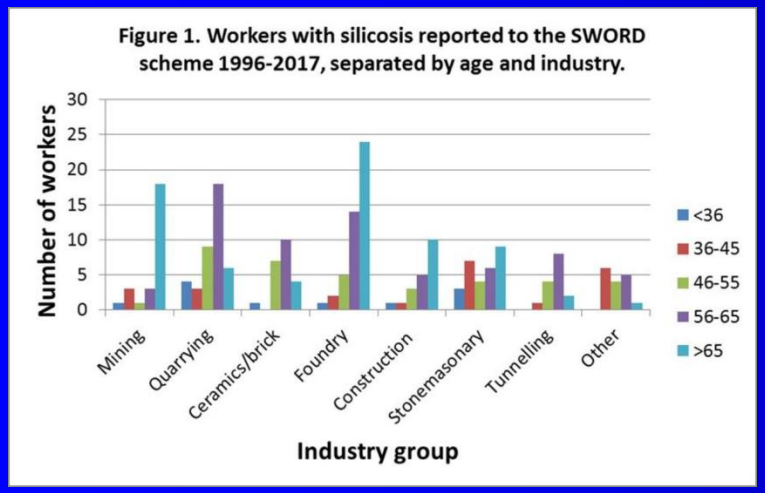
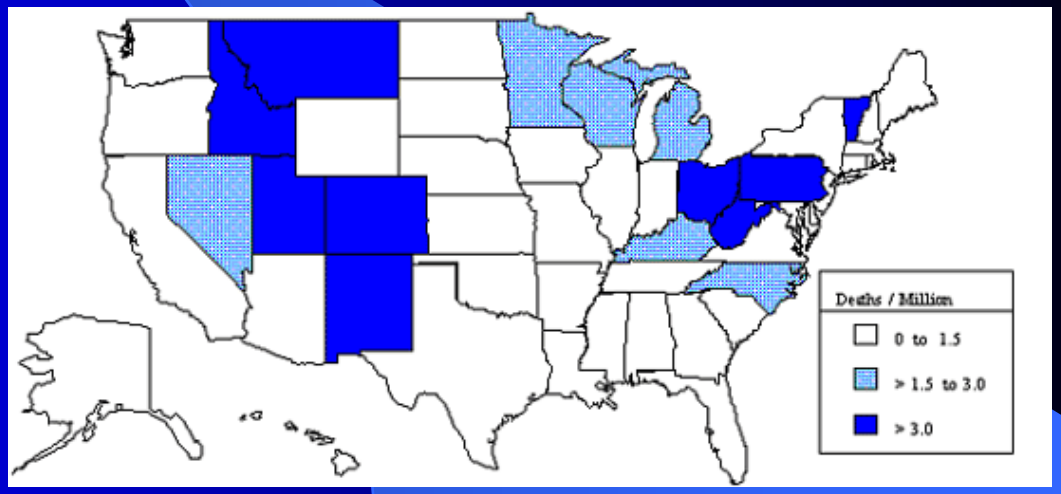


Figure 1. Workers with silicosis reported to the SWORD scheme 1996-2017, separated by age and industry.
Number of workers
30
25
20
15
10
5
0
Mining
Quarrying
Ceramics/brick
Foundry
Construction
Stonemasonary
Tunnelling
Other
Industry group
<36
36-45
46-55
56-65
>65


Deaths / Million
0 to 1.5
> 1.5 to 3.0
> 3.0