Health Assessment Section

Bureau of Environmental Health

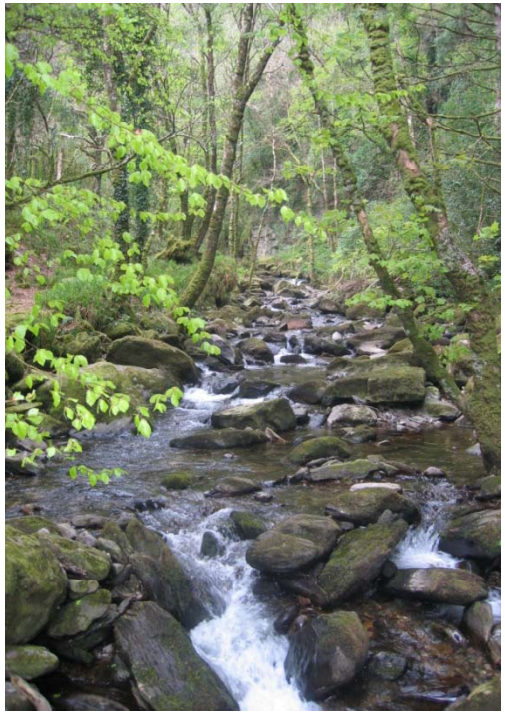
Chemical Compounds Commonly Detected in Ohio's Groundwater

Robert Frey, Ph.D. Geologist, Principle Investigator

Presented at Ohio's Annual Midwest Workshop in Environmental Health (2008)

- **Groundwater in Ohio contains naturally-occurring chemical constituents, both dissolved and suspended, present at trace levels (parts per billion ppb – low part per million ppm range) in all types of aquifers across the state.**

- **Chemicals include a variety of metals, salts, and other compounds, including oxides, carbonates, sulfates, and nitrates.**



Naturally-occurring Chemicals as Health Concerns

- **Some chemicals constituents, when present at the high-end of their range of natural concentrations in groundwater, can pose a potential health threat to people that drink untreated groundwater over an extended period of time.**

- **U.S. EPA established health-based drinking water standards (Maximum Contaminant Levels /MCLs) for these chemicals in public water supplies designed to be protective of public health.**

- **MCLs are established for chemicals like Arsenic, Lead, and Nitrate.**

Naturally-occurring Chemicals as Water Quality Issues

- **Other chemicals are water-quality rather than potential health concerns, where elevated levels of the chemical can cause aesthetic impairments (taste, odor, or color) or cosmetic effects (discoloration of teeth, skin, or fabrics).**

- **U.S. EPA established Secondary Maximum Contaminant Levels (SMCLs) for these chemicals to limit the development of these water quality issues.**

- **SMCLs established for chemicals like Iron, Manganese, Zinc, chloride, and sulfates.**

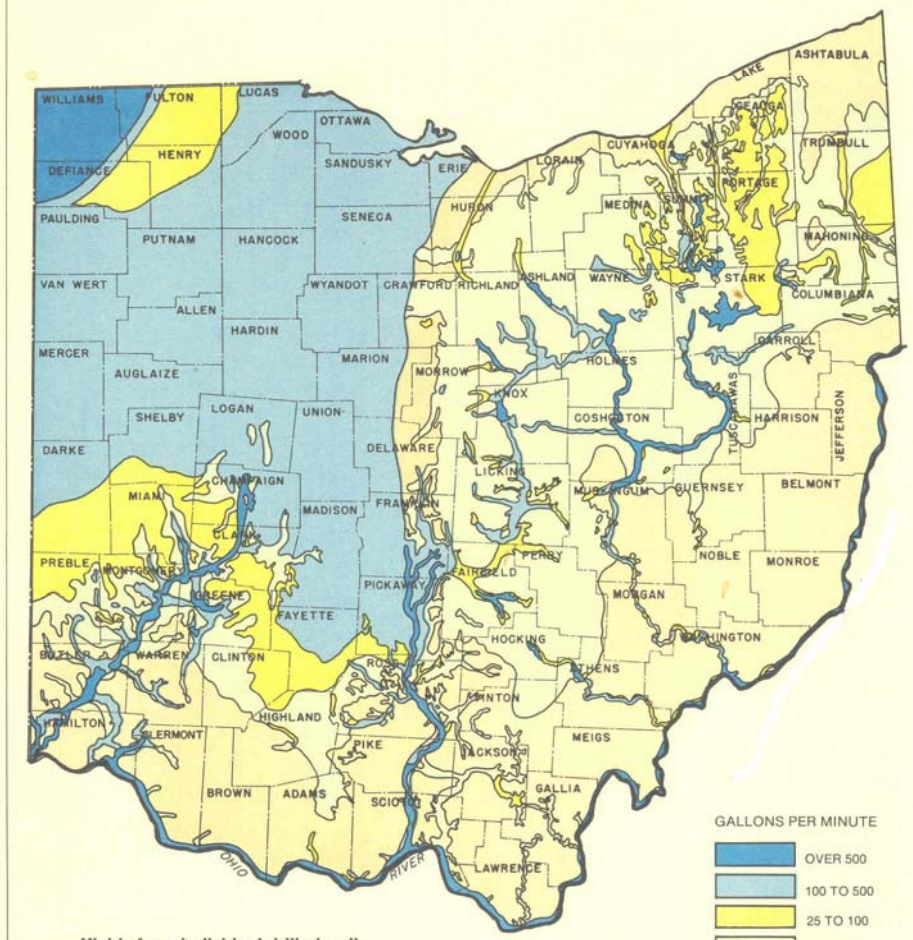
ODH and Private Well Water Safety & Quality

- **Ohio EPA's Division of Drinking and Groundwater regulates public water supplies for U.S. EPA in Ohio.**

- **ODH's Private Water Systems section uses the federal standards as advisory or guidance numbers to minimize water quality issues in private wells across the state.**

Groundwater Resource Map for Ohio

- **Private wells in Ohio obtain their water from groundwater obtained from a variety of aquifers across the state. These include Silurian carbonate bedrock in west-central Ohio; Carboniferous sandstones in eastern Ohio; and unconsolidated sand and gravel deposits in buried valley systems and outwash deposits associated with major river systems in the state (Ohio River, Great Miami River + its major tributaries [Stillwater, Twin Creek, Mad River], Little Miami River, Scioto River, Muskingum River + its major tributaries [Licking and Tuscarawas])**



Yields from individual drilled wells

ODNR
OHIO DEPARTMENT OF NATURAL RESOURCES

Naturally OHIO the best of it all!

GROUND-WATER RESOURCES IN OHIO

Richard F. Celeste
Governor

Lt. Gov. Myrl H. Shoemaker
Director

Ohio EPA's Ambient Groundwater Network

- **Ohio EPA's Ambient Groundwater Program has sampled naturally-occurring chemical constituents in groundwater in select wells drilled into these various aquifers across the state, sampling them on a regular basis for several decades. They have tabulated these results for each of the major aquifer types identified in the state, establishing a range for each major chemical constituent, including minimum, mean, and maximum values for each chemical in each major aquifer type.**

Review of Common Chemical Constituents in Ohio Groundwater

- **Constituents in Ohio Groundwater**
- **This presentation will review the occurrence, toxicology, health risk, and treatment options for a number of commonly-occurring chemical constituents in Ohio groundwater.**
- **Metals: Arsenic, Barium, Iron, Lead, Manganese, Strontium**
- **Others: Ammmonia, Nitrate, Sulfates**

Arsenic

Bureau of Environmental Health
Health Assessment Section
"To protect and improve the health of all Ohioans"

Arsenic
Answers to Frequently Asked Health Questions

What is arsenic?

Arsenic is an element found in nature. Arsenic has no smell or taste.

Where is the arsenic found in nature?

Natural arsenic is found in rocks. Ohio's rocks contain low levels of arsenic. We all have a small amount of arsenic in our bodies. Higher levels come from mining, some factories and chemical plants and wood treated products.

How do higher levels of arsenic get in the environment?

- **How does arsenic get in your body?**

1. Arsenic goes into the air when materials that contain arsenic are burned.
   - People then breathe in the smoke and arsenic (inhalation).
2. During the burning, arsenic falls from the air to the ground or into the rivers and lakes.
   - Kids play outside in the dirt (dermal-skin contact).
   - People have gardens or flower beds and have contact with the soil (dermal-skin contact).
   - People eat food that was grown in contaminated soil (ingestion-eating or drinking).
3. On the ground, arsenic will dissolve into the underground drinking water.
   - Humans then drink the water (ingestion-eating or drinking).

Who is more likely to come in contact with higher levels of arsenic?

- Private well users that live in areas with higher levels of natural arsenic in the rock.
- Kids who play outside in dirt with high levels of arsenic.
- People who have gardens or flower beds in soils with higher arsenic levels.
- People who drink water polluted by a nearby chemical plant or waste site.

Can you get sick from arsenic?

Yes, you can get sick from arsenic. But getting sick will depend on the type of arsenic and the contact (exposure) you had with this chemical.

Types of arsenic:
- Organic arsenic: This type can be found in food, especially seafood, and does not cause health problems.
- Inorganic arsenic: This type can be found in the soil, in the drinking water and in the air. This type sometimes causes health problems.

Exposure (contact) with the inorganic arsenic:
- How much you were exposed to (dose).
- How long you were exposed (duration).
- How often you were exposed (frequency).
- General Health, Age, Lifestyle
  Young children, the elderly and people with chronic (on-going) health problems are more at risk to chemical exposures.

Note that both types of arsenic occur naturally. But very high levels of inorganic arsenic in food or water can cause serious, sudden health problems or sometimes death.

Arsenic

- **Common, naturally-occurring element in earth's crust (20th most abundant element in crustal rocks)**
- **Arsenic levels in US soils averages 5 ppm**
- **Found in many geologic materials and a natural constituent of most groundwaters**
- **Groundwater tends to contain more arsenic than surface water.**

Arsenic in Ohio groundwater

OEPA indicates Arsenic levels in groundwater aquifers in the state range from:

- **Sandstone bedrock: ND – 78 ppb; mean value = 3.13 ppb**
- **Carbonate bedrock: ND -- 30 ppb; mean value = 4.01 ppb**
- **Sand & gravel: ND – 102 ppb; mean value = 5.79 ppb**

<u>NOTE:</u> Highest levels of arsenic (> 100 ppb) detected in deep wells drilled into buried valley S & G deposits across the state; with somewhat lower concentrations (12-35 ppb) in sandstones in NE Ohio and in Silurian dolomites in west-central Ohio

Arsenic Toxicology

- **A known, human cancer-causing substance (Carcinogen) health risks related to arsenic exposure via drinking water well-documented in human epidemiological studies (Taiwan, Bangladesh, Eastern India, Argentina, Chile, Utah).**

- **Studies indicate a distinct dose-related response to exposure to arsenic via drinking water and advent of adverse health effects**

Adverse Health Effects

Prolonged exposure (decade+) to elevated levels of arsenic in drinking water (170+ ppb -- 1,500 ppb):

- **Anemia**
- **Skin conditions (wart-like corns or keratoses + darkening of skin—hyper- pigmentation)**
- **Blackfoot's Disease (lack of circulation to distal extremities)**
- **Human carcinogen: increased incidence of skin and bladder cancer**

Drinking Water Standards

- **U.S. EPA MCL for Arsenic recently (2006) lowered to 10 ppb from 50 pbb**
- **Based on conclusive evidence of carcinogenicity in humans**
- **Increase in the number of public water systems out-of-compliance with regard to Arsenic – requires special treatment**
- **No real world evidence of adverse health effects, cancer or non-cancer, in humans drinking water with arsenic levels 10-50 ppb**

Drinking Water Treatment Systems

ODH Private Water Systems section recommends treatment of well water with arsenic levels in excess of 10 ppb or switching to an alternative safe water supply. Recommended systems to remove arsenic from well water included:

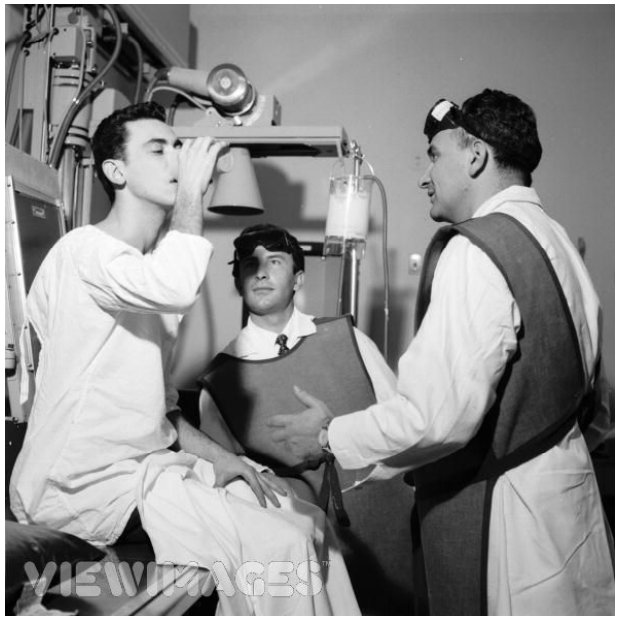
- **Coupled cation exchange/philox resin/anion exchange softener units**
- **Activated alumina cartridges**
- **Reverse Osmosis**
- **Advanced Adsorptive Media**

Barium

- Barium is a silvery, very dense metal that occurs in nature as compounds with carbonate and sulfate
- Both compounds occur in low-temp hydrothermal veins in carbonate host rocks
- Concentrated in residual clay deposits from weathering of carbonate bedrock
- Barium levels in US soils average 430 ppm
- Both compounds have low solubilities in water, limiting their occurrence in groundwater supplies

Barium in Ohio Groundwater

- **Sandstone bedrock: ND -- 2,080 ppb; mean value = 154 ppb**
- **Carbonate bedrock: ND -- 863 ppb; mean value = 72 ppb**
- **Sand & Gravel: ND -- 2,160 ppb; mean value = 177 ppb**

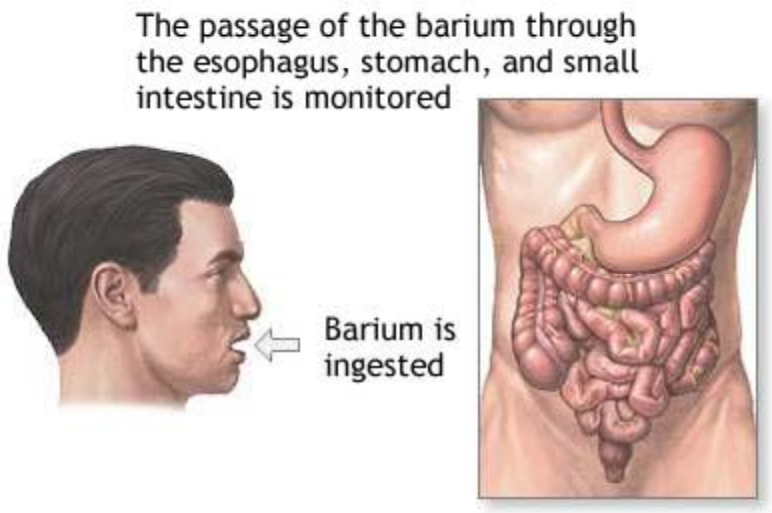


Barium Toxicology

- **Health effects from ingestion of barium through drinking water limited by lack of solubility of most naturally-occurring barium**

- **Documented health effects include mostly G-I effects and at much higher levels, blood pressure, respiratory, and CNS effects**

- **Not a human carci**



A.D.A.M.

Drinking Water Standards & Water Treatment Systems

- **U.S. EPA MCL for Barium = 2,000 ppb**

- **Barium is removed from raw water by cation-exchange water softener system**

Iron

- Iron is the most common metal in Earth's crust
- Solid metal in a variety of compounds: oxides, sulfides, silicates, carbonates, etc.
- Ubiquitous in all geologic materials and as soluble compounds in groundwater (insoluble oxides converted to soluble bicarbonate under low oxygen/high CO_2 conditions at depth)
- Often associated with other metals, i.e. manganese and arsenic, in groundwater

Iron in Ohio groundwater

- **Sandstone bedrock: <50 – 36,500 ppb; mean value = 1,617 ppb**
- **Carbonate bedrock: <50 – 96,700 ppb; mean value = 1,230 ppb**
- **Sand & Gravel: 20 – 70,000 ppb; mean value = 1,424 ppb**

Iron Toxicology

- **No known adverse health effects from ingestion of naturally-occurring iron via drinking water route**

Drinking Water Standards

- No health-based standards
- U.S. EPA SMCL (based on aesthetics: taste, color) = 300 ppb
- Upon exposure to oxygen in the air, soluble Ferrous converted to insoluble Ferric = water rusts -- orange precipitate -- “Red Water”

Drinking Water Treatment Systems

- Cation-exchange Water Softener systems
- Aerators
- Chemical treatments (chemical oxidation)

Lead

Bureau of Environmental Health
Health Assessment Section
"To protect and improve the health of all Ohioans"

Lead
Answers to Frequently Asked Health Questions

What is lead?
Lead is a naturally occurring bluish-gray metal found in small amounts of the earth's crust. Prior to our current knowledge of the health hazards of lead, it was widely found in many of the products we used every day. Products such as gasoline, paints, batteries, metal products and ammunition just to name a few. Because lead is toxic, its use has been dramatically reduced since the 1980's.

Lead in the environment:
Lead does not break down in the environment. And although lead occurs naturally in the environment, most of the high levels of lead found come from human activities.

Once lead falls on to soil, it usually sticks to the soil particles. If the soil is uncovered and open to the air or becomes disturbed, lead-contaminated dust is created and carried by the wind. This dust is easily breathed in or swallowed. With construction activities, the possibility of lead-contaminated dust is an important concern.

Gardens grown in lead-contaminated soils may contain lead. Produce of fruits, grains and vegetables (especially root vegetables such as beets, carrots, parsnips, radishes, turnips, and rutabagas) absorb some of the lead through their roots. There is also the possibility of lead-contaminated dust falling onto crops.

Inside the house, lead can be found in lead-based paint, lead-contaminated dust, older lead pipes that carry water and some glazed pottery. A child can easily eat lead paint chips, breathe or ingest the dust on their fingers.

How does lead get in your body?
You may be exposed to lead by breathing (inhalation), eating/drinking (ingestion) or by skin contact (dermal contact). However, only very small amounts of lead can get into your body through dermal contact. Inhalation and ingestion of lead-contaminated dust and soil are the main health concerns.

How does lead affect your health?
The harmful effects of lead are the same whether it is breathed or swallowed. The main target for lead toxicity is the nervous system, including the brain. But lead can negatively affect every organ of the body.

Children are most vulnerable to lead poisoning because they play outside, close to the ground or in the dirt. Small children also put their fingers in their mouths. Compared to adults, a bigger proportion of the amount of lead swallowed will enter the blood in children. About 99% of the amount of lead taken into the body of an adult will leave in the waste within a couple of weeks. But only about 32% of the lead taken into the body of a child will leave in the waste.

Lead exposure in the womb, in infancy, or in early childhood may also slow mental development and lower intelligence later in childhood. Lead can cause irritability and aggressive behavior in children. If pregnant women have high levels of lead in their bodies, fetuses exposed to lead in the womb may be born prematurely and have lower weights at birth. In some cases, pregnant women with high levels of exposure to lead may have miscarriages.

Some other harmful health effects of lead include damaged kidneys, damaged male reproductive system, severe "stomachaches," a poor appetite, sleep disorders, and hearing problems. Lead can also decrease reaction time and affect the memory.

Is there a medical test to determine whether I have been exposed to lead?
Yes, there is a test to see if you have been exposed to lead. The primary screening method is the measurement of total lead in the blood. This test can tell if you have been recently exposed to lead.

Also, exposure to lead can be evaluated by measuring the erythrocyte protoporphyrin (EP) in the blood sample. EP is a part of red blood cells known to increase when the amount of lead in the blood is high. However, the EP level is not sensitive enough to identify children with elevated blood lead levels below about 25 micrograms per deciliter (µg/dL). For this reason, total lead is the primary method of screening.

Lead can also be measured lead in teeth or bones by X-ray techniques. These tests can tell about long-term exposure but are not widely available..

Lead

- **Bluish-gray metal found in limited amounts in crustal rocks**

- **In Ohio, occurs as lead sulfide in isolated hydrothermal deposits in carbonates in western Ohio; trace element in coal deposits in E. Ohio Levels 9 – 39 ppm in Ohio agricultural soils; mean = 19 ppm**

- **Naturally-occurring lead compounds are not very soluble in most Ohio waters (pH >7.0)**

Lead in Ohio groundwater

- **Sandstone bedrock: ND – 40 ppb; mean value = 2.4 ppb**
- **Carbonate bedrock: ND –167 ppb; mean value = 2.9 ppb**
- **Sand & Gravel: ND – 785 ppb; mean value = 4.3 ppb**

Adverse Health Impacts

- **Exposure to high levels of lead via ingestion primarily impacts Central Nervous System (decrease reaction time & memory, slow mental development and lead to lower IQ in children, increase in behavioral problems); hearing and sleep disorders**

- **Kidney damage**

- **Severe nausea**

- **Reduced sperm production in males; increase in premature births & miscarriages in females**

- **Weak case for lead as a carcinogen – through the inhalation pathway**

Drinking Water Standards

- U.S. EPA has established a Lead "Action Level" of 15 ppb for public water supplies

Drinking Water Treatment Systems

- Bulk of the lead detected in private water systems in Ohio likely to result from leaching of lead solder from the distribution system rather than from raw well water
- Removed from tap water via cation exchange softener system
- Reverse Osmosis

Manganese

Bureau of
Environmental Health
Health Assessment Section

"To protect and improve the health of all Ohioans"

Manganese

(man' - guh - neez)

Answers to Frequently Asked Health Questions

What is manganese?

Manganese is an element found in nature. Pure manganese is a silver metal that has no special smell or taste. Pure manganese combines with other elements to form different manganese compounds.

Manganese is an essential (needed) nutrient that plays an important role in our health. Everyone comes in contact with small amounts of manganese in air, water, and food. Low levels of manganese are found in living things such as plants and animals. For nearly all people, food is the main source of manganese.

Manganese is also found in many types of rocks. Rocks with high levels of manganese compounds are mined and used to produce manganese metal. This metal is mixed with iron to make manganese steel.

Some manganese compounds are used in making batteries, found in diet supplements, and used as ingredients in some ceramics, pesticides, and fertilizers.

Can manganese make you sick?

Although manganese is a needed nutrient, you can get sick from breathing and eating or drinking (ingesting) high levels of manganese for long periods of time.

Getting sick will depend upon:

- How much you were exposed to (dose).
- How long you were exposed (duration).
- How often you were exposed (frequency).
- General Health, Age, Lifestyle
  Young children, the elderly and people with chronic (on-going) health problems are more risk to chemical exposures.

The health problems caused by breathing manganese dust include lung irritation and inflammation. It is likely that lung irritation begins shortly after exposure and continues for the duration of the exposure. *It is important to note that this inflammation and irritation is not unique to manganese-containing particles but is characteristic of nearly all particulate matter inhaled (such as dust, pollen, etc.).

It is unknown what effects occur at low-level exposures. Long-term exposure with manganese at very high levels may result in permanent neurological (brain and central nervous system) damage.

What are the health problems seen with exposure to manganese?

Health problems, especially problems with the brain and central nervous system, occur on a "continuum of dysfunction" that is dose-related. In other words, if you are exposed to normal levels of manganese, you would not expect to see any health problems. If you are exposed to increased lower levels of manganese, very mild or unnoticeable effects may be or may not be seen. Health problems appear to increase in severity as the exposure levels and duration increases.

People who have long-term exposure (contact) to high levels of manganese compounds may develop central nervous system problems which look like Parkinson's disease. This syndrome is called "manganism."

Symptoms include a general feeling of weakness, slow, clumsy movements with "heavy" arms and legs. Early symptoms also include slow or halting speech without tone or inflection and a dull and emotionless facial expression. Other symptoms include anorexia (severe weight loss), muscle pain, nervousness, irritability (emotionally upset), and headaches. People may be seem apathetic (a feeling of not caring) and dull. Other symptoms are impotence and loss of libido (sexual activity problems).

People who may have contact with higher levels of manganese include:

- Workers in a factory where manganese metal is produced or where manganese compounds are used to make steel or other products. In these factories workers would be exposed mainly by breathing in manganese dust if not *properly* protected.
- People who live near a factory that releases large amounts of manganese dust (particles) into the air.
- Community who live near a coal or oil burning factory because manganese is released into the air when these fossil fuels are burned.
- People who do not correctly use pesticides (bug killers) such as maneb and mancozeb will be exposed to higher levels.

Manganese

- Silvery metallic element found in crustal rocks and soils as compounds: oxides, carbonates, sulfates, and silicates

- Ubiquitous in soils, groundwater, and foods; often in association with iron

- Manganese Levels in US soils average 600 ppm

- Compounds more soluble than iron -- common constituent of groundwater (same chemistry as iron – dissolves in presence of CO_2 and low oxygen at depth)

Manganese in Ohio groundwater

- **Sandstone bedrock: ND – 1,910 ppb; mean value = 205 ppb**
- **Carbonate bedrock: ND -- 300 ppb; mean value = 30 ppb**
- **Sand & Gravel: ND –10,880 ppb; mean value = 226 ppb**

Adverse Health Impacts

- Essential nutrient for good health in humans (bone mineralization; protein formation, metabolic regulation)
- Most manganese in body comes from food
- Long-term exposure to very high levels of manganese (>1,800 ppb) in drinking water may cause central nervous system disorders in elderly (lack of muscular control, tremors)
- Not a human carcinogen

Drinking Water Standards

- **No Health-based MCL**
- **Lifetime Health Advisory = 300 ppb**
- **U.S. EPA SMCL (based on aesthetics: taste and color) = 50 ppb**
- **Upon exposure to oxygen in air, soluble manganese bicarbonate (clear) converts to manganese oxide -- black precipitate – “Black Water”**

Drinking Water Treatment Systems

- Cation-exchange water softener system
- Aerators
- Chemical treatments (chemical oxidation)

Strontium

- Minor constituent in minerals in crustal rocks
- Forming compounds with other chemicals, including sulfate (celestite) and carbonate (strontianite), primarily in carbonate rocks with gypsum
- Both compounds are soluble in water
- Radioactive isotope 90 Sr = fallout from nuclear explosions; reactors

Strontium in Ohio groundwater

- **Sandstone bedrock: ND – 7,480 ppb; mean value = 530 ppb**
- **Carbonate bedrock: ND – 66,200 ppb; mean value = 17,870 ppb**
- **Sand & Gravel: ND – 30,800 ppb; mean value = 1,905 ppb**

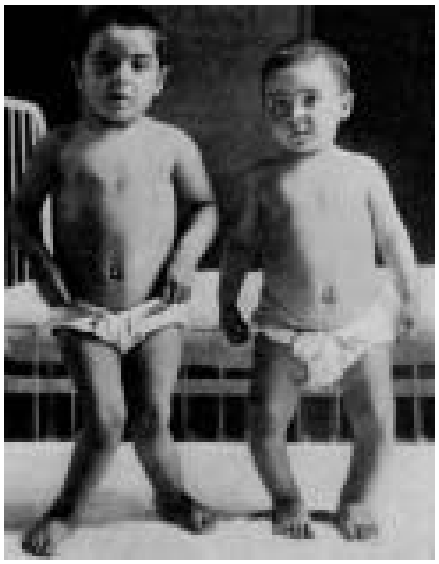
Adverse Health Impacts

- **Ingestion of large amounts of strontium, coupled with a calcium-poor diet – disrupt bone chemistry – "strontium rickets"**

- **Radioactive 90Sr – taken up by bone – attacks bone marrow & soft tissues – anemia and leukemia**

- **Naturally-occurring strontium is not a human carcinogen**

- **Radioactive 90Sr is a known human carcinogen**



Drinking water standards

- No health-based MCL
- Lifetime Health Advisory = 4,000 ppb
- Drinking Water Equivalent Level = 20,000 ppb
- ATSDR Intermediate Exposure Guide = 70,000 ppb adults/20,000 ppb

Drinking Water Treatment Systems

- Cation-exchange water softener system
- Reverse Osmosis

Questions:

For More Information:

Health Assessment Section
Ohio Department of Health
Bureau of Environmental Health

Robert Frey, Ph.D., ***Chief, Principle Investigator***

Peter Ferron, ***Environmental Scientist***

John Kollman, ***Toxicologist***

Greg Stein, ***Community Involvement/Health Education***

Laurie Billing, ***Epidemiologist***

Ohio Department of Health
Bureau of Environmental Health
Health Assessment Section
246 N. High Street
Columbus, Ohio 43215
Phone: (614) 466-1390
Fax: (614) 466-4556
E-mail: BEH@gw.odh.state.oh.us