How is Drinking Water Regulated?

US Environmental Protection Agency identifies contaminants and creates rules to protect public health
- Safe Drinking Water Act

Ohio EPA adopts and enforces the regulations
- Ohio Revised Code 6109: Safe Drinking Water
- Ohio Administrative Code 3745: Environmental Protection Agency
- If the director thinks there is a public health risk he can make rules
  - Harmful algal blooms and lead
Safe Drinking Water Act

Enacted in 1974, major amendments in 1986 and 1996
- Required the promulgation of primary drinking water regulations to ensure safe drinking water
- Covers both microbial and chemical contaminants
- Gave enforcement (primacy) to state governments
- Created both National Primary (enforceable) and Secondary (non-enforceable, aesthetic) Drinking Water Regulations
- Some current rules:
  - Surface Water Treatment Rule
  - Lead and Copper Rule
  - Disinfectants/Disinfection By-products Rule
  - Ground Water Rule
  - Public Notification Rule and Consumer Confidence Rule
  - Unregulated Contaminant Monitoring Rule

The Regulatory Balancing Act

Microbials:
- *Giardia*
- viruses
- *Crypto*

Disinfection byproducts:
- TTHMs
- HAA5
- Bromate

Acute Microbial Infections (Short-term) → Health Effects → Chronic Cancer (Long-term)
### Ohio Public Water Systems

- Regulated by the Ohio EPA
- Approximately 4,800 Public Water Systems in Ohio
- They serve over 11 million people
- Range in size from churches, schools and gas stations to large municipalities
- Use both surface water and ground water
- Simple treatment to complex multi-barrier
- Operated by licensed water operators
- Tested by certified laboratories and analysts

### City of Columbus Public Water System

- In 2016, Columbus provided over 49 billion gallons of safe, clean drinking water to over 1.1 million people throughout the Central Ohio region
- Clean, safe drinking water is truly a public health business
- Some quick facts about the Columbus Water System Infrastructure:
  - 3 Water Plants – 2 surface water and 1 ground water
  - 5 Reservoirs (Hoover, O'Shaughnessy, Griggs, Doutt and Alum Cr.)
  - 3,530 Miles of water main maintained by the City of Columbus
    - (2,520 miles owned by Columbus; 1,010 miles owned by suburbs)
  - 26 Booster stations operated and maintained
    - (15 owned by Columbus; 11 owned by the suburbs)
  - 37 Water tanks operated storing ~79 Million Gallons
    - (26 owned by Columbus; 11 owned by the suburbs)
  - 25,700 Fire hydrants owned by the City of Columbus
**Service Area**

- **2016 Annual Volume**
  - Hap Cremean
  - Dublin Rd.
  - Parsons Ave. (groundwater)

- 7.8 Billion Gal
- 16.2 Billion Gal
- 25.5 Billion Gal

- 84% surface water
- Service population 1.16 million

**Water Quality Monitoring**

- Monitor year-round from the upper reaches of our watershed through the plant to the customer’s tap
- Have process control labs at all 3 plants
- Dedicated compliance lab with 14 full time staff
- Conduct nearly 50,000 tests annually
- Real-time online monitors in all reservoirs and plant intakes
- 20 real-time online monitors throughout the distribution system
Primary Goals of Water Treatment

- Protect public health
- Kill disease causing organisms
- Remove sediment
- Remove unwanted chemicals
- Produce water that has a pleasant appearance and taste
- Meet USEPA Drinking Water Regulations and Ohio EPA (OEPA) Drinking Water Rules

Multi-barrier Treatment

Step 1: Screening
Step 2: Coagulation/sedimentation
Step 3: Lime softening
Step 4: Recarbonation
Step 5: Intermediate ozone
Step 6: Biologically active carbon filtration
Step 7: Disinfection
Step 8: Storage and distribution
Step 9 (Future): Anion exchange (nitrates)
Step 10 (Future): UV light disinfection
Step 1: Screening

- Removes leaves, sticks and fish

Step 2: Coagulation

- Removes suspended particles
- Enhanced coagulation for total organic carbon
- Remove algae
- Potassium permanganate – oxidant
- Powder Activated Carbon – adsorbent
Step 3: Lime-soda Softening

- High pH used to soften the water
- Removes heavy metals (Fe, Mn, As, Hg)
- Removes additional total organic carbon
- Another step to reduce particles

Step 4: Recarbonation

- Used to lower pH after softening
- Stabilizes water
- All of the pH changes damages and/or kills bacteria and algae
Step 5: Intermediate Ozone

- Strong oxidant – Breaks down large organic compounds into smaller ones (assimilable organic carbon)
- Used to reduce organics and atrazine
- Works well for lots of contaminants of emerging concern
- Taste and odor control
- Oxidizes algal toxins
- New process $70 million HCWP and $50 million DRWP

Intermediate Ozone Treatment

Before

After
Step 6: Biologically Active Carbon Filtration (BAF)

- Removes remaining particles
- Bacteria on filters consume organic compounds
- Used to reduce TOC and atrazine
- Works well for lots of contaminants of emerging concern
- Taste and odor control
- Primary reason Columbus installed ozone/BAF is to reduce disinfection byproducts

Step 7: Disinfection

- Use chlorine as the disinfectant
- Used as primary and secondary disinfectant
- Kills disease causing bacteria
- Oxidizes algal toxins

Image source: www.waterhelp.org
Step 8: Storage and distribution

- Add fluoride
- Add corrosion inhibitor
- Each plant has 12-24 hours of treated water storage
- Have multiple clearwells at each plant
- Range in size from 4.5 million gallons to 18 million gallons

Step 9 (Future): Ion Exchange

- Anion exchange using nitrate selective resin
- Only at the Dublin Road Water Plant
- Once finished in 2018 will be largest in US
- Designed to treat highest historical nitrate (15 mg/L) for the longest duration (21 days)
Step 10 (Future): UV disinfection

- Uses Ultraviolet light to inactivate disease-causing microorganisms, including chlorine resistant organisms such as Cryptosporidium and Giardia
- Significantly enhances public health protection

Water Quality Issues in the News

Nitrate
Lead
*Cryptosporidium*
Algae – toxins and taste and odor
Nitrate Levels Increase At Dublin Water Plant

10TV.com

Columbus warns residents about nitrates in water
Associated Press, The News-Herald

The Maximum contaminant level (MCL) for nitrate is 10 ppm

Common sources: agricultural fertilizer, sewage, livestock manure, home septic systems and lawn fertilizer

Nitrate is essentially harmless to most people, but is considered an acute toxin to infants under 6 months of age

In infants it causes a condition known as methemoglobinemia, or “blue-baby syndrome,” which can be fatal.

Nitrate

- The Maximum contaminant level (MCL) for nitrate is 10 ppm
- Common sources: agricultural fertilizer, sewage, livestock manure, home septic systems and lawn fertilizer
- Nitrate is essentially harmless to most people, but is considered an acute toxin to infants under 6 months of age
- In infants it causes a condition known as methemoglobinemia, or “blue-baby syndrome,” which can be fatal.
What’s Columbus Doing?

- Columbus has had nitrate advisories in 2015 and 2016
- Currently treatment can’t remove nitrate – dissolved ion in water
- Work in watershed with partners to reduce nutrient runoff
- Routine monitoring – above OEPA requirements
- Online real-time monitoring
- Only an issue at one of our plants – DRWP
- Installing $40 million anion exchange treatment system

Lead

Flint Water Crisis

Source for plant image: Pinterest  Source for Flint image: Blueskiesfalling (Connor Coyne)
Lead

- The Action Level (AL) for lead in 15 ppb
- Lead leaving water plants has no detectable lead
- Possible sources of lead in water: lead service lines, lead solder prior to 1986, brass fixtures prior to 2014
- Other sources of lead: lead paint and dust, pottery, jewelry and toys
- OEPA recently required all PWS to map known sources of lead in their system
  http://epa.ohio.gov/ddagw/pws/leadandcopper/map.aspx

What’s Columbus Doing?

- All routine testing has shown Columbus in compliance with the LCR
  - Highest level detected was 2.7 ppb, almost all were below detection
- Have optimized corrosion control program
- Add a corrosion inhibitor
- Routine monitoring – above OEPA requirements
- Replace lead lines when come across them during maintenance or project
- Provide public education on lead
- Created an interactive map for customers to find lead lines
  www.columbus.gov/utilities/water-protection/wqal/Lead-in-Drinking-Water/
- Best way to reduce lead exposure is to flush the tap for at least 30 seconds if it hasn’t been used for several hours
In response to Milwaukee crypto outbreak USEPA expanded on the Surface Water Treatment Rule by creating the Interim Enhanced Surface Water Treatment Rule.

- Designed to strengthen control of microbial contaminants, especially crypto
- Established tighter requirements for turbidity
- Required systems to monitor source water for crypto
- No MCL or AL for crypto, but if a system finds crypto in its source it is required to install additional treatment
What’s Columbus Doing?

- Have multi-barrier treatment for removal Coagulation, softening, ozone, and filtration
- Routine monitoring – above OEPA requirements
- Have detected low levels of *cryptosporidium* in the source water
- $30 million project to install UV disinfection at both surface water plants as an additional barrier

Algae

Source: NASA
Algae

- Algae can produce taste and odors (T&O) or toxins or nothing
- No regulation on T&O – aesthetic problems
- Harmful Algal Blooms (HABs) come from cyanobacteria
- OEPA recently established action levels for the microcystin toxin 0.3 ppb for children under six, pregnant women, nursing mothers, dialysis patients and people with liver conditions 1.6 ppb for all individuals
- OEPA also has threshold levels for several algal toxins
- OEPA requires surface water systems to monitor weekly for algae and toxins
- OEPA has a HAB website: http://www.epa.ohio.gov/ddagw/hab.aspx

<table>
<thead>
<tr>
<th>Drinking Water Threshold</th>
<th>Micosystin</th>
<th>Anatoxin-a</th>
<th>Cylindrospermopsin</th>
<th>saxitoxin</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not drink – children under 6 and sensitive populations</td>
<td>0.3</td>
<td>20</td>
<td>0.7</td>
<td>0.2</td>
</tr>
<tr>
<td>Do not drink – children 6 and older and adults</td>
<td>1.6</td>
<td>20</td>
<td>3</td>
<td>0.2</td>
</tr>
<tr>
<td>Do not use (recreational no Contact Advisory)</td>
<td>20</td>
<td>300</td>
<td>20</td>
<td>3</td>
</tr>
</tbody>
</table>

Source: Ohio EPA

What’s Columbus Doing?

- Have monitored for algae since the 1938
- Algae are present year-round
- Experience algae blooms almost every year and had several T&O events
- Sporadically detected low levels of toxins in source water
- Have monitored since 2006
- Working in watershed to reduce nutrient runoff
- Have many tools to address both toxins and T&O
  - Removal of algae – coagulation, softening, filtration
  - Oxidants – chlorine, ozone, permanganate
  - pH changes – high pH breaks down toxins and T&O compounds
  - Adsorbent – carbon, we have spent up to $10,000 per day
  - Assimilation – biological filtration
Drinking Water Safety

Katrina Johnson, MD
Assistant Professor – Clinical
Department of Internal Medicine
Department of Pediatrics
The Ohio State University Wexner Medical Center

Drinking Water Safety

- Lead
- Cryptosporidiosis
- Nitrates
Objectives

• Identify Sources
• Identify Risk Factors
• Symptoms
• Diagnosis
• Treatment
• Prevention

Lead
### Flint and the Lead Crisis

- April 2014 Cost-Saving Redirection of water supply
- From Lake Huron to the Flint River
- Increased Corrosive Water due to addition of ferric chloride
- Purpose to decrease trihalomethanes from organic matter.
- Causing Metal to dissolve
- Lead Pipe in new water source corroded

### Flint, Michigan

- BLL in Flint 3x higher before the crisis
- Contamination x18 months after recognition
- 20-32% of homes with lead concentration >15ug/L
- 2013-2015 BLL incidence increased from 2.5%-4.9%

- Back story
  - 4/10 families live below poverty level
  - Soil and dust levels increased
  - Increased % of nutritional deficiency
Lead- Sources

- Dust and Soil.
- Water- solder
- Renovation
- Auto, Plumbing, Gun exposure
- House, Toy or Furniture paint before 1960.
- Cosmetics-Indian surma

Lead- Risk Factors

- Lower socioeconomic class
- Homes built prior to 1960
- Adoptees and Immigrants
- Children- Ingestion
- Infants- Formula Fed
- Calcium and Iron deficiency
Lead- Symptoms

- Abdominal pain
- Anemia
- Peripheral neuropathy
- Mental status changes
- Headache
- Decreased cognition
- Hearing loss
- Hyperactivity

Diagnosis

- Cut off BLL > 10ug/dL
- No Safe Blood lead level (BLL)!
  Acutely
  - Venous vs capillary testing
  Chronically
  - X-rays of Long bones
  - KUB
Lead Screening

- 2012 BLL $\geq$ 2ug/dL Retest!
- Peak BLL 18-36 months (oral fixation)
- BLL peak velocity 6-12 months (iron deficiency)

<table>
<thead>
<tr>
<th>Blood level</th>
<th>Recheck</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;10 ug/dL</td>
<td>Not defined</td>
</tr>
<tr>
<td>10-19 ug/dL</td>
<td>1-3 months</td>
</tr>
</tbody>
</table>

- Peak Lead Season June (lowest March)

Lead Screening

- Screening at 12 and 24 month well child visit
- 24-72 months and No previous blood lead test, must receive one.
- Medicaid Requirement requires 2 blood tests.
# Lead- Treatments

- #1 Remove the Source
- Any BLL $\geq 45\text{ug/dL}$ Chelation and Cathartic

<table>
<thead>
<tr>
<th>Route</th>
<th>Drug</th>
<th>BLL 45-70 ug/dL</th>
<th>BLL $&gt;70$ ug/dL</th>
<th>BLL $&gt;70$ ug/dL + encephalopathy</th>
</tr>
</thead>
<tbody>
<tr>
<td>oral</td>
<td>DMSA</td>
<td>✔</td>
<td>✔ b</td>
<td></td>
</tr>
<tr>
<td>oral</td>
<td>Penicillamine</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>iv</td>
<td>Ca $\text{Na}_2$ EDTA</td>
<td>Required</td>
<td>✔</td>
<td></td>
</tr>
<tr>
<td>iv</td>
<td>BAL</td>
<td>✔ a</td>
<td>✔</td>
<td></td>
</tr>
</tbody>
</table>

## Treatment Side Effects

- Elevated liver enzymes
- Urinary Sediment
- GI distress
- Neutropenia
# Lead- Prevention

- Eliminate Leaded Gasoline
- Eliminate Lead to seal perishables
- Regulate Lead in House Paint
- School Drinking Fountains in most states are not regulated.
- Aging Turf
- Recalls at US Consumer Product Safety Commission
  - [https://www.cpsc.gov/](https://www.cpsc.gov/)
  - 3rd party testing

---

# Lead- Prevention

- **National Lead Prevention Week**
  October 22-28 2017

Source: CDC
Lead

- Long term effects on Cognition
- Average IQ deficit of 6.1 points BLL ≥5 ug/dL

<table>
<thead>
<tr>
<th>Blood lead Level</th>
<th>Effects</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;5 ug/dL</td>
<td>Lower IQ scores</td>
</tr>
<tr>
<td></td>
<td>Inattention</td>
</tr>
<tr>
<td></td>
<td>Antisocial</td>
</tr>
<tr>
<td>&lt;10 ug/dL</td>
<td>Delayed Puberty</td>
</tr>
<tr>
<td></td>
<td>Hearing Loss</td>
</tr>
</tbody>
</table>

Created based on Table 2 of Prevention of Childhood Lead Toxicity. Pediatrics. 2016. Jul 138 (1)

Cryptosporidiosis
Dublin and Columbus Close Pools

- Late July 2016 Franklin and Delaware county 1st detection
- Closed all pools, splash pads and Scioto Mile fountains-August
- By September 8\(^{th}\) there were over 600 cases
- By September 22\(^{nd}\) 792 cases
- Largest outbreak in 15 years
- Last outbreak was in 2008, 350 cases

Cryptosporidium

- Parasite
- Outer Shell
- Most commonly spread by ingestion of contaminated water

Source: CDC

https://www.cdc.gov/dpdx/cryptosporidiosis/index.html
## Cryptosporidium- Sources

- Fecal- oral
  - Swimmers
  - Infected kids via diapers
  - Infected cattle
  - Drinking water from Lakes or Rivers

- Incidence of 748,000 cases per year

## Cryptosporidiosis- Symptoms

- Watery diarrhea
- Incubation 2-10 days
- Duration 1-4 weeks
- Associated symptoms:
  - Abdominal pain
  - Cramping
  - Nausea and vomiting
  - Fever, weight loss
  - Dehydration
  - Reactive arthritis
Cryptosporidiosis- Diagnosis

- Reportable Disease
- Stool testing
  - Acid fast staining
  - Direct Fluorescent Antibody
  - Enzyme Immunoassays
  - Molecular (PCR)

Cryptosporidiosis- Treatment

- Nitazoxanide –Approved in 2002
  - No drug-drug interaction
  - Pregnancy class B
  - Effectiveness in immunocompromised unclear.

<table>
<thead>
<tr>
<th>Age</th>
<th>Dose</th>
<th>Frequency</th>
<th>Duration</th>
</tr>
</thead>
<tbody>
<tr>
<td>12-47 months</td>
<td>100mg</td>
<td>BID</td>
<td>3 days</td>
</tr>
<tr>
<td>4-11 yo</td>
<td>200mg</td>
<td>BID</td>
<td>3 days</td>
</tr>
<tr>
<td>&gt;12 yo</td>
<td>500mg</td>
<td>BID</td>
<td>3 days</td>
</tr>
</tbody>
</table>
## Cryptosporidiosis - Treatment

### Nitazoxanide Availability
- 100mg/5mL Strawberry
- 500mg tablet
- Take with food! 2x better bioavailability

### Mechanism of Action
- Anaerobic bacteria it Inhibits an enzyme essential in anaerobic metabolism (pyruvate-ferredoxin oxidoreductase )
- Cryptosporidium and Giardia it works to inhibit sporozoite growth, unknown.

### Side effects of Nitazoxanide
- <1% Abdominal pain, diarrhea, nausea
- Anorexia, or increased appetite
- Flatulence'
- Enlarged salivary glands
- Increased sCr
- Increased ALT
- Discolored urine
- Ocular discoloration

### Costs about $457/6 tabs
Cryptosporidiosis - Prevention

- Wash with Soap and Water
- No swimming x2 weeks
- Don’t drink Lake or River Water
- Use a Filter made for cyst removal.
- Avoid undercooked foods
- Avoid ice cream when out of the country
- Barrier method and Avoid oral-anal contact

Cryptosporidiosis - Prevention

- Recreational water
  - Supplement chlorination with UV radiation or Ozone
  - These inactivate Cryptosporidium
- CDC includes
  - Rifabutin or clarithromycin when used for MAC prophylaxis in HIV can help.
# Nitrates and Methemoglobinemia

## Source of Methemoglobinemia

<table>
<thead>
<tr>
<th>Source of Methemoglobinemia</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Pedi” drugs</td>
<td>The -caines, silver nitrate</td>
</tr>
<tr>
<td>Smoke inhalation</td>
<td>Fire fighters, smokers, Mechanics</td>
</tr>
<tr>
<td>Antibiotics</td>
<td>Dapsone, sulfonamides</td>
</tr>
<tr>
<td>Antimalarials</td>
<td>Chloroquine, primaquine</td>
</tr>
<tr>
<td>Nitrates</td>
<td>Well/ drinking water</td>
</tr>
<tr>
<td>Nitrites</td>
<td>Cured meats, sausages</td>
</tr>
</tbody>
</table>

Summary chart based on Table 1 of Theobald DL et al. The Beef Jerky Blues: Methemoglobinemia from Home Cured Meat. Pediatric Emergency Care. 2016 Sept
### Nitrate warning in Columbus, Ohio

- **June 2016 Nitrate Warning**
- **Hard rains**
- **Fertilizer drains into Scioto River**
- **Warnings:**
  - Pregnant women >30 weeks gestation
  - Infants <6 months old
  - Included Grandview, to Grove City, Hilliard area.
  - Requires notification >10ppm
  - Ave 5-6ppm

### Methemoglobinemia

- **Hemoglobinopathy**
- **Acquired or Congenital**
- **Review of Carbon Monoxide**
  - CO increased affinity for Hgb over O\(_2\)
  - Decreased O\(_2\) delivery
- **Methemoglobinemia**
  - Oxidized heme iron increased O\(_2\) affinity (ferric)
  - Almost No oxygen delivered.
  - >50% Fatal
Methemoglobinemia

• Congenital
  – Mutations causing iron to be in Ferric state
  – Or mutations impairing return from methemoglobin to Hgb (Methemoglobin reductase)

• Acquired Methemoglobinemia
  – Toxins oxidize heme iron
  – Nitrates
  – Nitrites

Methemoglobinemia- Symptoms

• Hypoxia
• Cyanotic with high PaO2.
• Palpitations
• Dyspnea
• Altered mental status
• Muddy brown blood draw

And a history to include Nitrite or other oxidant ingestion
**Methemoglobinemia - Diagnosis**

- Co-oximetry
- Oxygen saturation Gap (ABG vs pulse ox)
- Serum level of nitrites and offending drug
- Rule out hemolysis, liver and renal function
- Hgb electrophoresis to detect Hgb M (hereditary causes)
- Methemoglobin enzyme assay- (hereditary causes)

**Methemoglobinemia - Treatment**

- Methylene blue
- 1mg/kg Emergently
- Then 60mg 3-4x/ day
- Or Ascorbic acid 300mg -600mg/day
Methemoglobinemia - Prevention

- Limit and Regulation
  - Fertilizer run off
  - OTC and prescription drug use
  - Drug disposal
  - Measure nitrate level

References

4. Bellinger, David C. Title Lead Contamination in Flint — An Abject Failure to Protect Public Health Source N. Engl. J. Med., 2016, 374, 12, 1101-1103, Massachusetts Medical Society