

City of Columbus Water Treatment Process

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City of Columbus

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)

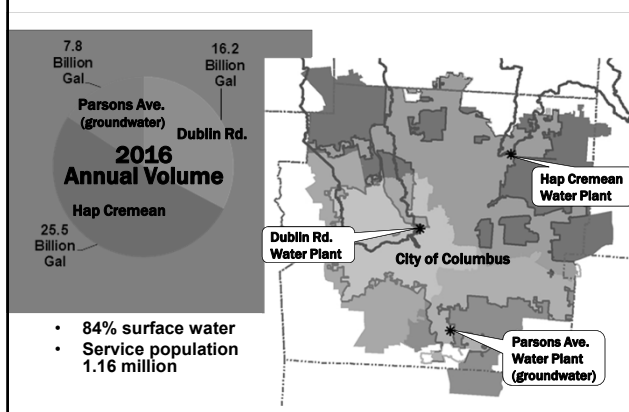
Ohio Public Water Systems

- 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, Douth 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



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

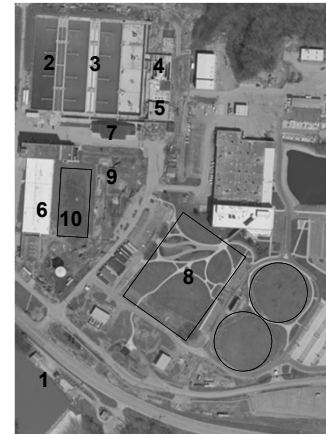


Primary Goals of Water Treatment

- 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



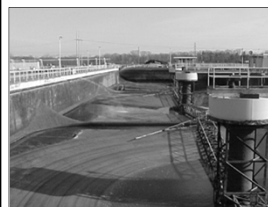
Step 1: Screening

- 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



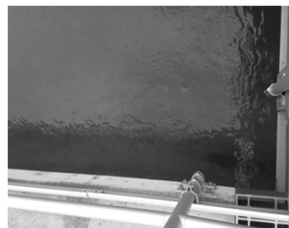
Step 5: Intermediate Ozone

- 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

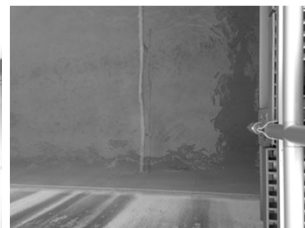


Intermediate Ozone Treatment

Before

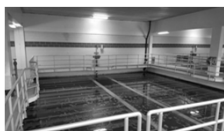


After



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

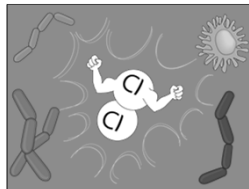


Image source: www.waterhelp.org



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



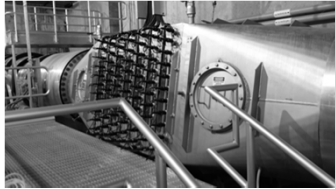
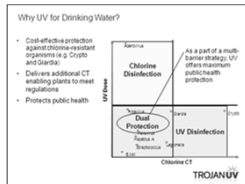
Step 9 (Future): Ion Exchange

- 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

Nitrates Start Debate For Second Water Safety Law

HOME CAMPUS SPORTS A-E OPINION MULTIMEDIA

Home » Campus » Area » Columbus issues nitrate water advisory

Columbus issues nitrate water advisory

By Michael Hester, hester@10tv.com June 8, 2015

The city of Columbus issued a nitrate advisory Monday to Columbus residents living in parts of the city receiving water supplied by the Dublin Road Water Plant.



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.

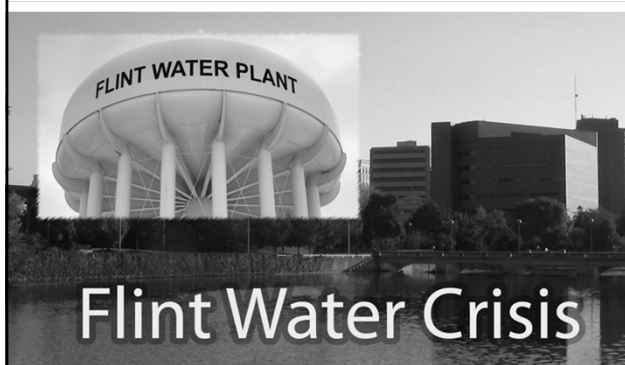


Author: Thirteen of Clubs

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



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

Cryptosporidium

Milwaukee, 1993: The Largest Documented Waterborne Disease Outbreak in US History

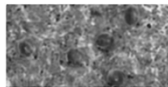
January 10, 2014 — Leave a Comment

101 11 11 11 5

An Interview with Dr. Stephen Gradus, Ph.D., MT(ASCP), D(ABMM), City of Milwaukee Health Department

Waterborne disease outbreaks are relatively rare events in our time, but just over two decades ago, Milwaukee experienced the largest documented drinking water outbreak in US history. Caused by the chlorine-resistant parasite *Cryptosporidium parvum* the outbreak affected over 400,000 people—25 percent of Milwaukee's population in 1993—and resulted in over \$96 million in combined healthcare costs and productivity losses, according to a study by the US Centers for Disease Control and Prevention. We contacted Dr. Stephen Gradus, Director of the City of Milwaukee Health Department Public Health Laboratories Division since 1990, for a look back at the event, including lessons learned, and improvements implemented:

What was the first sign of trouble in Milwaukee in 1993, and how did the health department respond?



Microphotograph of *Cryptosporidium parvum* oocysts. Image courtesy of the US Centers for Disease Control and Prevention.

Source: www.waterandhealth.org

Cryptosporidium

- 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>

Drinking Water Threshold	Microcystin (ppb/L)	Anatoxin-a (ppb/L)	Cylindrospermopsis (ppb/L)	Saxitoxins (ppb/L)
Do Not Drink - children under 6 and sensitive populations	0.3	20	6.7	0.2
Do Not Drink - children 6 and older and adults	1.6	20	3	0.2
Do Not Use (Recreational No Contact Advisory)	20	300	20	3

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

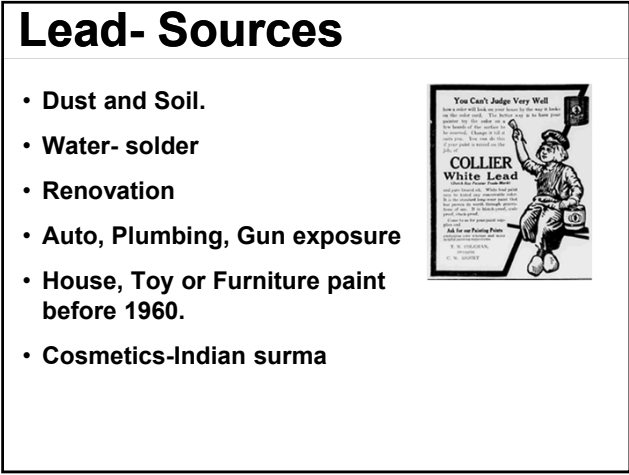
- BLL in Flint 3x higher before the crisis
- Contamination x18 months after recognition
- 20-32% of homes with lead concentration >15ug/L
- 2013- 2015 BLL incidence increased from 2.5%-4.9%
- Back story
 - 4/10 families live below poverty level
 - Soil and dust levels increased
 - Increased % of nutritional deficiency

Lead- Sources

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





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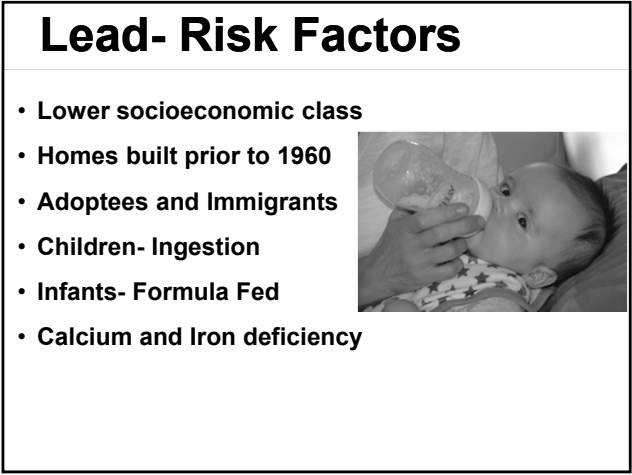


Lead- Risk Factors

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

A black and white photograph showing a close-up of a baby's face and upper body. The baby is lying down, looking up towards the camera. A hand is holding a glass bottle with a white cap, feeding the baby. The baby is wearing a light-colored shirt with a dark star pattern. The background is dark and out of focus.

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Lead- Symptoms

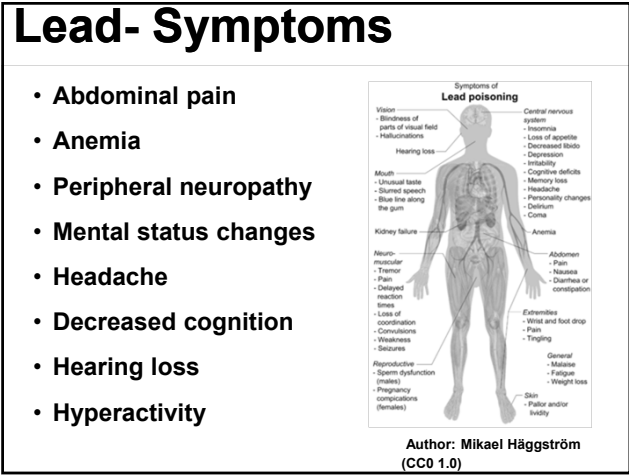
- Abdominal pain
- Anemia
- Peripheral neuropathy
- Mental status changes
- Headache
- Decreased cognition
- Hearing loss
- Hyperactivity

The diagram illustrates the symptoms of lead poisoning across various body systems. The central figure is a human silhouette with lines pointing to specific organs and systems, each associated with a list of symptoms.

- Central nervous system**
 - Headache
 - Loss of appetite
 - Decreased libido
 - Depression
 - Irritability
 - Cognitive deficits
 - Memory loss
 - Headache
 - Personality changes
 - Chromium
 - Coma
- Vision**
 - Blindness of parts of visual field
 - Hallucinations
- Hearing loss**
- Mouth**
 - Unusual taste
 - Stained speech
 - Blue line along the gum
- Kidney failure**
- Anemia**
- Abdomen**
 - Pain
 - Nausea
 - Vomiting or constipation
- Neuro-muscular**
 - Tremor
 - Pain
 - Delayed reaction times
 - Loss of coordination
 - Convulsions
 - Weakness
 - Seizures
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 - Wrist and foot drop
 - Pain
 - Tingling
- Reproductive**
 - Sperm dysfunction (males)
 - Pregnancy complications (females)
- General**
 - Malaise
 - Fatigue
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 - Pallor and/or icteric

Author: Mikael Häggström (CCO 1.0)

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Diagnosis


- Cut off BLL > 10ug/dL
- No Safe Blood lead level (BLL)!

Acutely

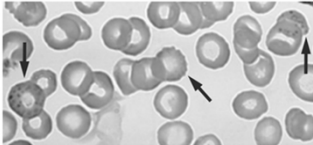
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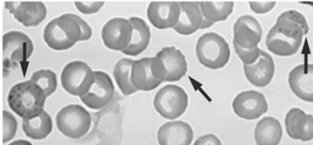
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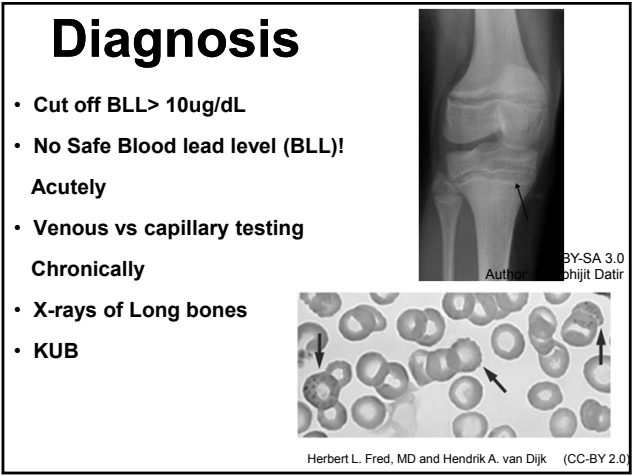
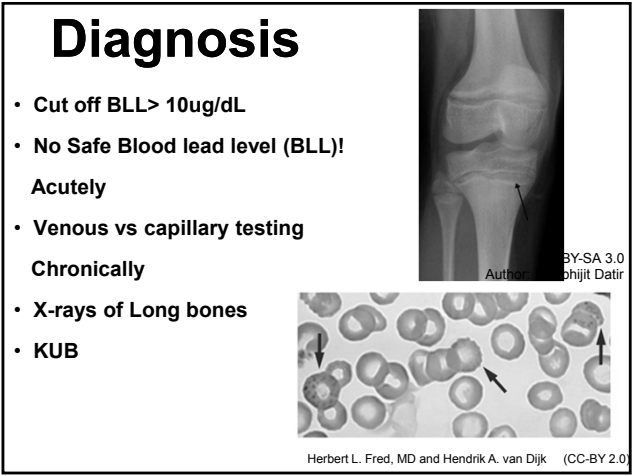


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Author: Ghijit Datir



Herbert L. Fred, MD and Hendrik A. van Dijk (CC-BY 2.0)

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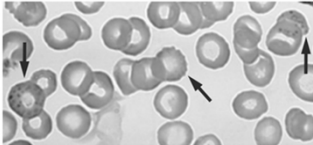
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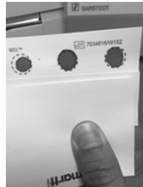


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Lead Screening

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

Blood level	Recheck
<10 ug/dL	Not defined
10-19 ug/dL	1-3 months



- 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 45ug/dL Chelation and Cathartic

Route	Drug	BLL 45-70 ug/dL	BLL >70 ug/dL	BLL >70 ug/dL + encephalopathy
oral	DMSA	✓	✓ b	
oral	Penicillamine			
iv	Ca Na ₂ EDTA		Required	✓
iv	BAL		✓ a	✓

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/>
 - 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

Blood lead Level	Effects
<5 ug/dL	Lower IQ scores Inattention Antisocial
<10 ug/dL	Delayed Puberty Hearing Loss

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

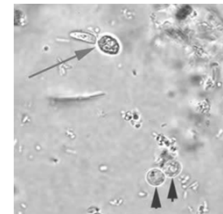
Cryptosporidiosis

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 8th there were over 600 cases
- By September 22nd 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.

Age	Dose	Frequency	Duration
12- 47 months	100mg	BID	3 days
4- 11 yo	200mg	BID	3 days
>12 yo	500mg	BID	3 days

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.

Cryptosporidiosis- Treatment

- 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	Examples
"Pedi" drugs	The -caines, silver nitrate
Smoke inhalation	Fire fighters, smokers, Mechanics
Antibiotics	Dapsone, sulfonamides
Antimalarials	Chloroquine, primaquine
Nitrates	Well/ drinking water
Nitrites	Cured meats, sausages

Summary chart based on Table 1 of Theobald DL et. 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

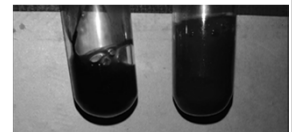
- Hemoglobinopathy
- Acquired or Congenital
- Review of Carbon Monoxide
 - CO increased affinity for Hgb over O₂
 - Decreased O₂ delivery
- Methemoglobinemia
 - Oxidized heme iron increased O₂ affinity (ferric)
 - Almost No oxygen delivered.
 - >50% Fatal

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



George T, Shaikh AI, Thomas L, Kundavaram AP. Severe methemoglobinemia due to insecticide poisoning. Indian J Crit Care Med 2014;18:113-4. (CC BY-NC-SA)

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



Source: Pinterest

Methemoglobinemia- Prevention

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

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