WATER QUALITY 101

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INTRODUCTION

OBJECTIVE

- CONTINUING EDUCATION FOR COLORADO LAWYERS
- PROVIDE BASIC UNDERSTANDING OF TECHNICAL ASPECTS OF WATER QUALITY

OUTLINE

- LEGAL FRAMEWORK
- BASIC INDICATORS OF WATER QUALITY
- SURFACE WATER QUALITY FRAMEWORK
- EXAMPLES
- OTHER WATER QUALITY INDICATORS

LEGAL FRAMEWORK

- CLEAN WATER ACT (CWA) - 1972
  - 33 U.S.C. §1251 *ET SEQ.*
  - ESTABLISHES BASIC STRUCTURE FOR REGULATING DISCHARGES OF POLLUTANTS INTO WATERS OF THE UNITED STATES
  - REGULATES WATER QUALITY STANDARDS FOR SURFACE WATER
  - NATIONAL WATER QUALITY CRITERIA RECOMMENDATIONS FOR POLLUTANTS IN SURFACE WATER
  - REGULATION OF GROUNDWATER IS RESERVED FOR STATES

- SAFE DRINKING WATER ACT (SDWA) – 1974
  - 42 U.S.C. §300F *ET SEQ.*
  - PROTECTS DRINKING WATER QUALITY IN THE U.S.
  - FOCUSES ON ALL WATER ACTUALLY OR POTENTIALLY USED FOR DRINKING, WHETHER FROM SURFACE WATER OR GROUNDWATER

LEGAL FRAMEWORK – CONT'D

COLORADO WATER RIGHT DETERMINATION AND ADMINISTRATION ACT OF 1969

- C.R.S. § 37-92-101 *ET SEQ.*
- C.R.S. § 37-92-305(3A):

  "A CHANGE OF WATER RIGHT, IMPLEMENTATION OF A ROTATIONAL CROP MANAGEMENT CONTRACT, OR PLAN FOR AUGMENTATION, INCLUDING WATER EXCHANGE PROJECT, SHALL BE APPROVED IF SUCH CHANGE, CONTRACT, OR PLAN WILL NOT INJURIOUSLY AFFECT THE OWNER OF OR PERSONS ENTITLED TO USE WATER UNDER A VESTED WATER RIGHT OR A DECREED CONDITIONAL WATER RIGHT."

- C.R.S. § 37-80-120(3):

  "ANY SUBSTITUTED WATER SHALL BE OF A QUALITY AND CONTINUITY TO MEET THE REQUIREMENTS OF USE TO WHICH THE SENIOR APPROPRIATION HAS NORMALLY BEEN PUT."

LEGAL FRAMEWORK – CONT'D

- COLORADO WATER QUALITY CONTROL ACT (WCQA) - 1973
  - C.R.S. § 25-8-101 ET SEQ.
  - C.R.S. § 25-8-201: WATER QUALITY CONTROL COMMISSION (WQCC)
    - RULE-MAKING BODY
    - ESTABLISHES DESIGNATED USES FOR SPECIFIC WATER BODIES
    - ESTABLISHES SPECIFIC WATER QUALITY REQUIREMENTS TIED TO DESIGNATED USES
    - WATER QUALITY CONTROL DIVISION ADMINISTERS DISCHARGE PERMITS AND OTHER CWA ELEMENTS
  - C.R.S. § 25-8-204: WATER QUALITY STANDARDS
    - ESTABLISHES BASIC WATER QUALITY STANDARDS FOR SURFACE WATER AND GROUNDWATER
    - WATER QUALITY STANDARDS TO BE BASED ON BENEFICIAL USE OF THE WATER, AMONG OTHER THINGS

LEGAL FRAMEWORK – CONT'D

GOLDEN AUGMENTATION PLAN CASE (CASE NO. 83CW361)

- GOLDEN PROPOSED TO TAKE 20 CFS OUT OF PRIORITY AT ITS INTAKE ON CLEAR CREEK
- IN EXCHANGE, GOLDEN PROPOSED TO SUBSTITUTE WASTEWATER TREATMENT EFFLUENT UPSTREAM OF RAW WATER SUPPLIES FOR CITIES OF WESTMINSTER AND THORNTON, AND IRRIGATION WATER SUPPLIED BY FRICO.
- GOLDEN'S WASTEWATER TREATMENT PLANT WAS IN COMPLIANCE WITH THEIR NPDES PERMIT
- COURT ANALYZED THE CASE BASED ON WATER QUALITY PROVISIONS IN C.R.S. § 37-80-120, C.R.S. § 37-92-305(5), AND C.R.S. § 37-80-120, C.R.S. § 37-92-305(3).
- COURT FOUND FOR OBJECTORS, AND THAT OBJECTORS WOULD BE INJURED DUE TO:
  - INCREASING CONCENTRATIONS OF HARMFUL CHEMICALS IN OBJECTORS' RAW WATER SUPPLY.
  - INCREASES IN CANCER AND DISEASES AMONG OBJECTORS' CUSTOMERS
  - IMPACTS ON AGRICULTURE, INCLUDING ADDITIONAL DISEASES IN ANIMALS AND CONTAMINATION OF CROPS
  - ECONOMIC INJURY DUE TO INCREASED ALGAE GROWTH IN RESERVOIR, REQUIRING MORE TREATMENT

LEGAL FRAMEWORK – CONCLUSIONS

- THERE ARE PROMULGATED WATER QUALITY STANDARDS UNDER FEDERAL LAW THAT OWNERS OR USERS OF WATER SOURCES MUST COMPLY WITH.

- ADDITIONALLY, COLORADO'S WATER RIGHT DETERMINATION AND ADMINISTRATION ACT OF 1969 ALLOWS WATER USERS TO DETERMINE WATER QUALITY CRITERIA BASED ON THEIR BENEFICIAL USE OF WATER.

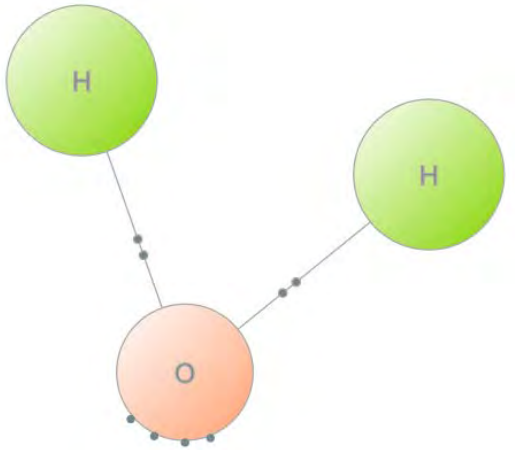
- THEREFORE, IT IS POSSIBLE FOR A WATER USER TO FULLY COMPLY WITH APPLICABLE LAWS, BUT STILL INJURE OTHER WATER USERS BASED ON THE BENEFICIAL USE CRITERIA.

BASIC INDICATORS OF WATER QUALITY

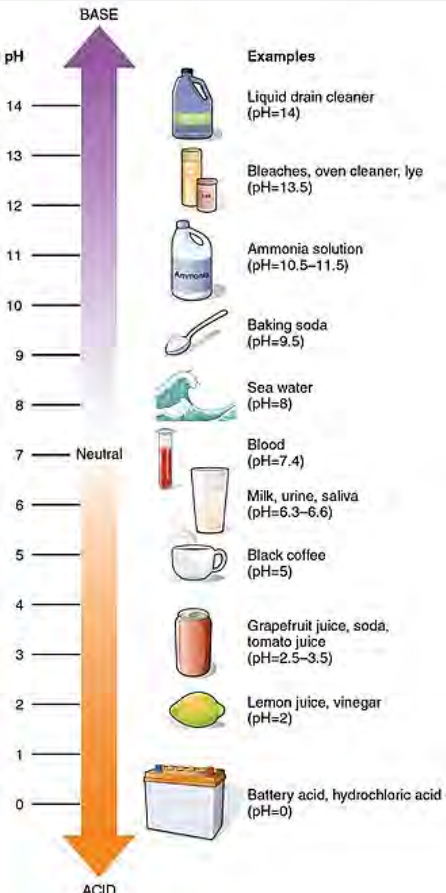
- PH
- TOTAL DISSOLVED SOLIDS (TDS)
  - HARDNESS
  - SODIUM ABSORPTION RATIO (SAR)
  - INORGANIC CONSTITUENTS AND METALS
- DISSOLVED OXYGEN
- PATHOGENS
- NUTRIENTS (NITRATE, PHOSPHATE, POTASSIUM)
- ORGANIC CHEMICALS
- DISINFECTANTS AND DISINFECTION BYPRODUCTS

WHAT IS PH?
WHY IS PH IMPORTANT?

$H_2O \rightarrow H^+ + OH^-$



- PH IS A LOGARITHMIC SCALE USED TO EXPRESS THE ACIDITY OR BASICITY OF WATER.
- WHEN WATER MOLECULES BREAK APART, OR IONIZE, THEY FORM HYDROGEN AND HYDROXIDE IONS
- PH EXPRESSES THE BALANCE BETWEEN HYDROGEN AND HYDROXIDE IONS IN WATER.
- PH IS CRITICAL TO THE MAINTENANCE OF HUMAN LIFE.
- PH AFFECTS THE FERTILITY OF SOILS, THE HEALTH OF AQUATIC LIFE, AND THE HEALTH OF AGRICULTURAL CROPS.
- ALL LIVING ORGANISMS HAVE A SPECIFIC RANGE OF PH IN WHICH THEY THRIVE, BUT OUTSIDE OF THAT THEY CANNOT SURVIVE.
- PH AFFECTS THE WAY WATER INTERACTS WITH MATERIALS. ACIDIC WATER CAN CORRODE METAL STRUCTURES AND WEAKEN CONCRETE.
- PH CONTROLS THE SOLUBILITY OF METALS AND OTHER CHEMICALS IN WATER.



WHAT IS TDS?
WHY IS TDS IMPORTANT?

Gypsum ($CaSO_4$)

Calcite ($CaCO_3$)

TDS = TOTAL DISSOLVED SOLIDS.

TDS IS MEASURED IN UNITS OF MILLIGRAMS OF DISSOLVED SOLIDS PER LITER OF WATER:

MG/L ALSO KNOWN AS PARTS PER MILLION (PPM).

1 MG/L IS EQUIVALENT TO 6 POUNDS OF SALT IN AN OLYMPIC-SIZE SWIMMING POOL.

THE MOST COMMON SOLIDS DISSOLVED IN NATURAL WATERS ARE:

SEA/TABLE SALT – NACL

ROAD SALT – $MGCL_2$

MINERALS: CALCITE, GYPSUM

X 6

SIMPLE WATER CLASSIFICATION BASED ON TOTAL DISSOLVED SOLIDS

CATEGORY	TDS (MG/L OR PPM)
FRESH WATER	0 – 1,000
BRACKISH WATER	1,000 – 10,000
SALINE WATER	10,000 – 100,000
BRINE WATER	> 100,000
POTABLE FOR HUMANS	0 – 1,000*
POTABLE FOR LIVESTOCK	<5,000*

* Depending on jurisdiction.

MAJOR AND MINOR CONSTITUENTS THAT MAKE UP TDS

MAJOR CONSTITUENTS (> 5 MG/L)

- CALCIUM
- MAGNESIUM
- SODIUM
- CHLORIDE
- SULFATE
- ALKALINITY
- SILICON

MINOR CONSTITUENTS (0.01 TO 10 MG/L)

- BORON
- FLUORIDE
- IRON
- NITRATE (NUTRIENT)
- POTASSIUM
- STRONTIUM

ONE IMPLICATION OF TDS: WATER HARDNESS

WATER HARDNESS

= 2.5(CALCIUM) + 4.1(MAGNESIUM)

SOFT: 0 – 60 MG/L

MODERATELY HARD: 61 – 120 MG/L

HARD: 121 – 180 MG/L

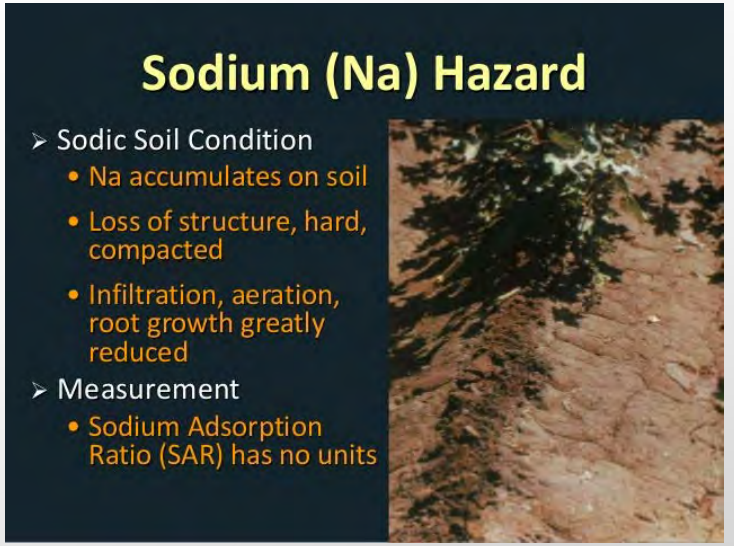
VERY HARD: >180 MG/L

WHY HARDNESS MATTERS: LEAVES A RESIDUE, CAUSES SCALING, CLOGS PIPES, RAISES COST OF HEATING WATER, CAN CAUSE KIDNEY STONES AND OTHER HEALTH AFFECTS.

ANOTHER IMPLICATION OF TDS: SODIUM ABSORPTION RATIO

SODIUM ABSORPTION RATIO (SAR)

$$SAR = \frac{Na}{\sqrt{\frac{Ca + Mg}{2}}}$$



- IRRIGATION WATER QUALITY PARAMETER.
- INDICATES SUITABILITY OF WATER FOR USE IN IRRIGATION.
- GENERALLY, LOW SAR VALUES (< 3) INDICATE THE WATER IS SAFE FOR CROP IRRIGATION AND HIGHER VALUES (> 9) INDICATE THE WATER MAY NOT BE SAFE FOR CROP IRRIGATION.
- HOWEVER, PROPER INTERPRETATION OF SAR MUST BE PERFORMED IN CONJUNCTION WITH OTHER FACTORS SUCH AS SOIL TYPE, CROP TYPE, AND SALT CONTENT.

TRACE CONSTITUENTS THAT MAY BE PRESENT IN TDS (<0.1 MG/L)

- ALUMINUM
- ANTIMONY
- ARSENIC
- BARIUM
- BERYLLIUM
- BISMUTH
- BROMIDE
- CADMIUM
- CERIUM
- CESIUM
- CHROMIUM
- COBALT
- COPPER
- GALLIUM
- GERMANIUM
- GOLD
- INDIUM
- IODIDE
- LANTHANUM
- LEAD
- LITHIUM
- MANGANESE
- MOLYBDENUM
- NICKEL
- NIOBIUM
- PHOSPHATE
- PLATINUM
- RADIUM
- RUBIDIUM
- RUTHENIUM
- SCANDIUM
- SELENIUM
- SILVER
- THALLIUM
- THORIUM
- TIN
- TITANIUM
- TUNGSTEN
- URANIUM
- VANADIUM
- YTTERBIUM
- ZINC

- Many of these constituents can be toxic to humans, fish, and crops if present at high enough concentrations.
- Most of these constituents have federally-mandated Maximum Contaminant Levels (MCLs) for drinking water.

WATER QUALITY IN THE NEWS: FLINT, MICHIGAN

April 2014 – The water supply for the City of Flint, Michigan was switched from Lake Huron to the Flint River.

May 2014 – Many residents reported discolored water started coming out of their faucets.

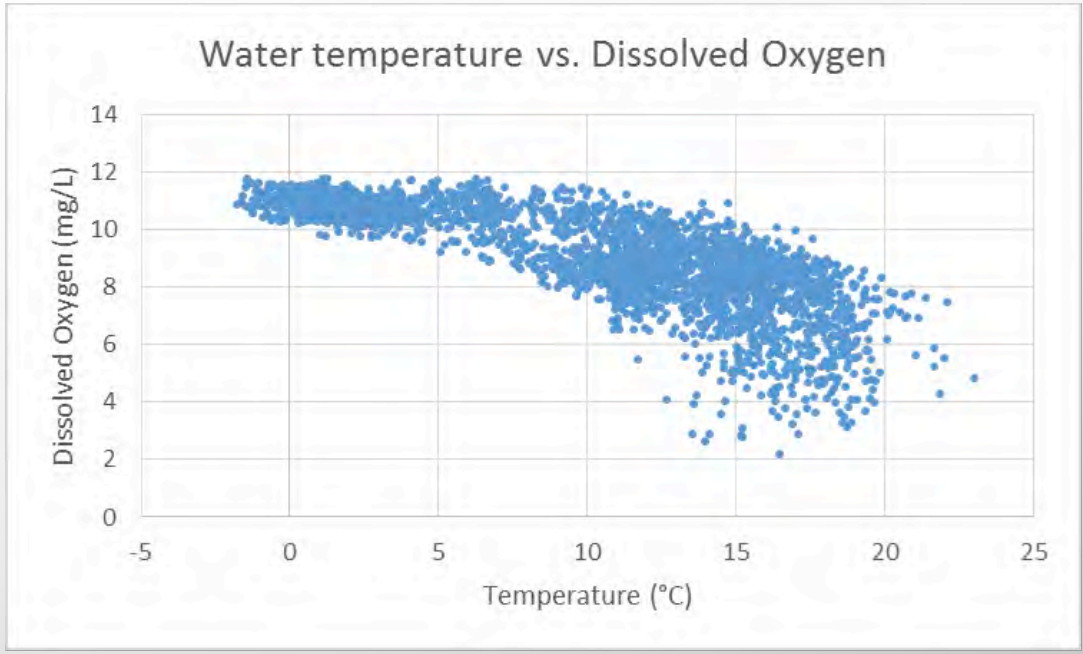
February 2015 – EPA and MDEQ obtained sampling data showing high levels of lead in Flint drinking water, memo in July.

August 2015 – Virginia Tech scientists perform independent research study of Flint's drinking water problem.

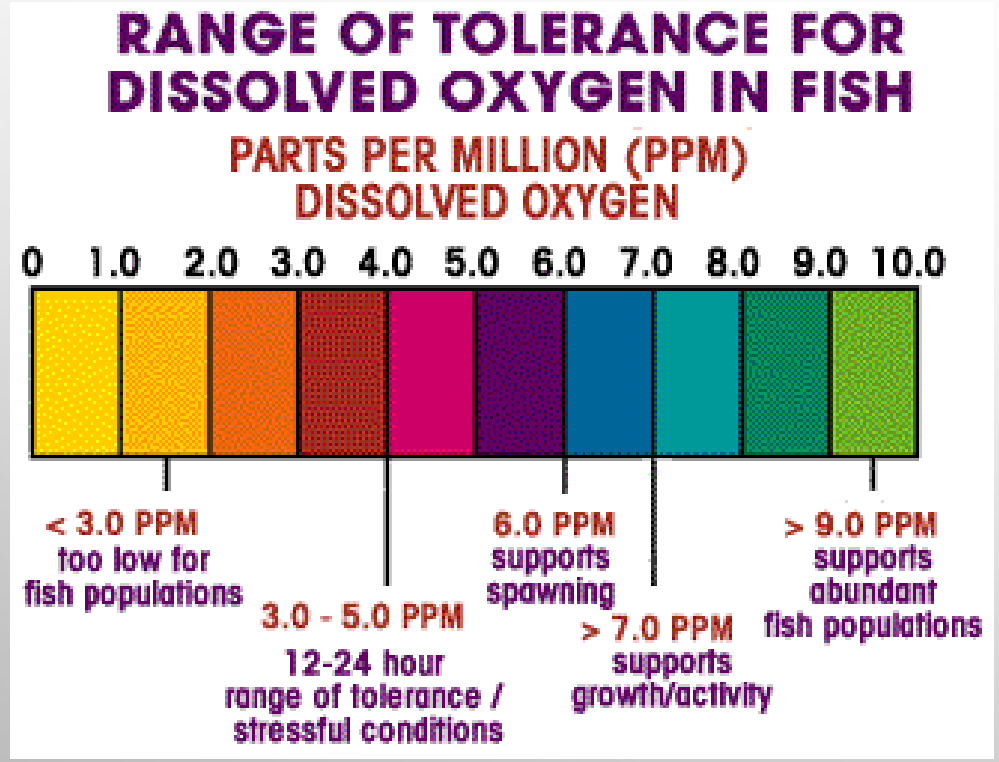
- High levels of lead in a statistically significant number of residential water samples, with reproducibility.
- The cause of the problem is corrosion and leaching of lead out of pipes.

WHAT IS DISSOLVED OXYGEN? WHY IS DO IMPORTANT?

- GASES SUCH AS OXYGEN AND CARBON DIOXIDE CAN DISSOLVE IN WATER.
- DISSOLVED OXYGEN CAN BE PRESENT IN NATURAL WATERS UP TO A LEVEL OF APPROXIMATELY 10-12 MG/L.
- DISSOLVED OXYGEN IN WATER IS VITAL FOR SURVIVAL AND MAINTENANCE OF FISH AND AQUACULTURE.
- DISSOLVED OXYGEN ALSO EXERTS AN IMPORTANT CONTROL ON THE SOLUBILITY OF SOME METALS.
- DISSOLVED OXYGEN CAN ALSO CAUSE CORROSION OF UNDERWATER METAL STRUCTURES.

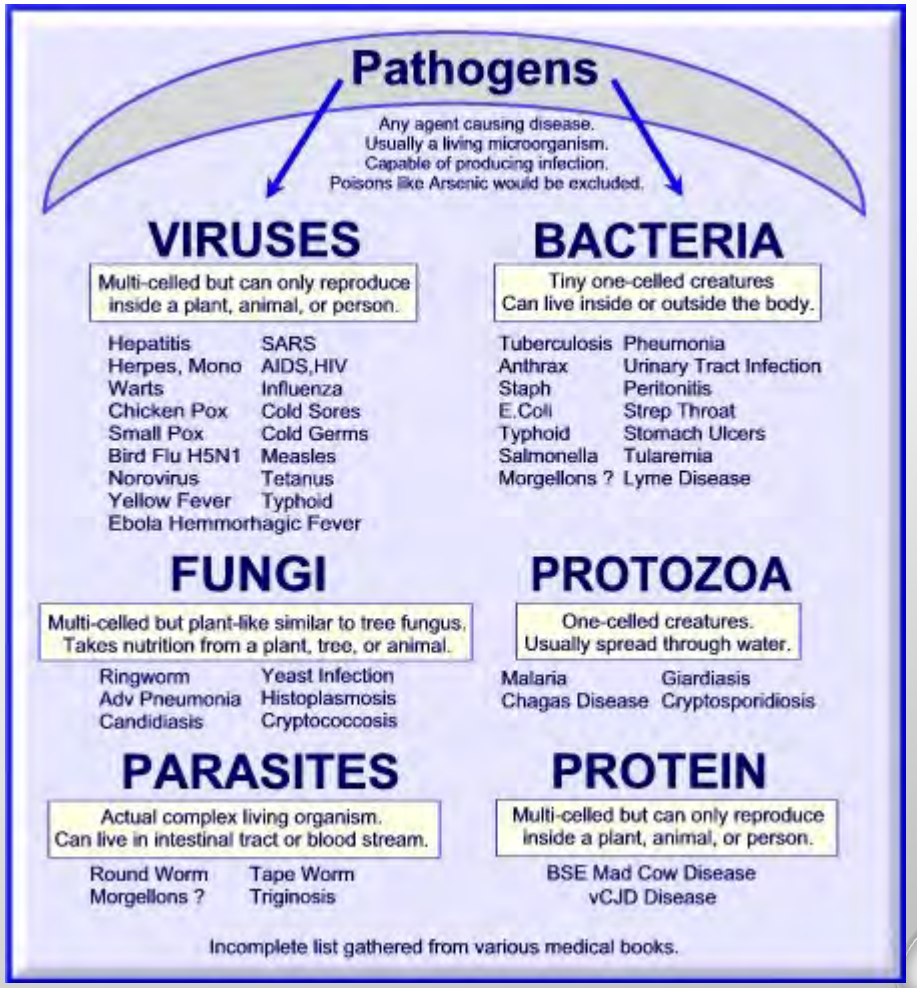


DISSOLVED OXYGEN – CONT'D



PATHOGENS

- PATHOGEN: DISEASE-CAUSING MICROORGANISM
- EXAMPLES:
  - BACTERIA
    - CERTAIN STRAINS OF E. COLI
    - NOT ALL BACTERIA, AND NOT ALL STRAINS OF E. COLI, ARE PATHOGENS
  - PARASITES
    - GIARDIA
    - CHRYPTOSPORIDIUM
  - VIRUSES
    - NOROVIRUS GI
    - HEPATITIS A
    - NOT ALL VIRUSES ARE PATHOGENS

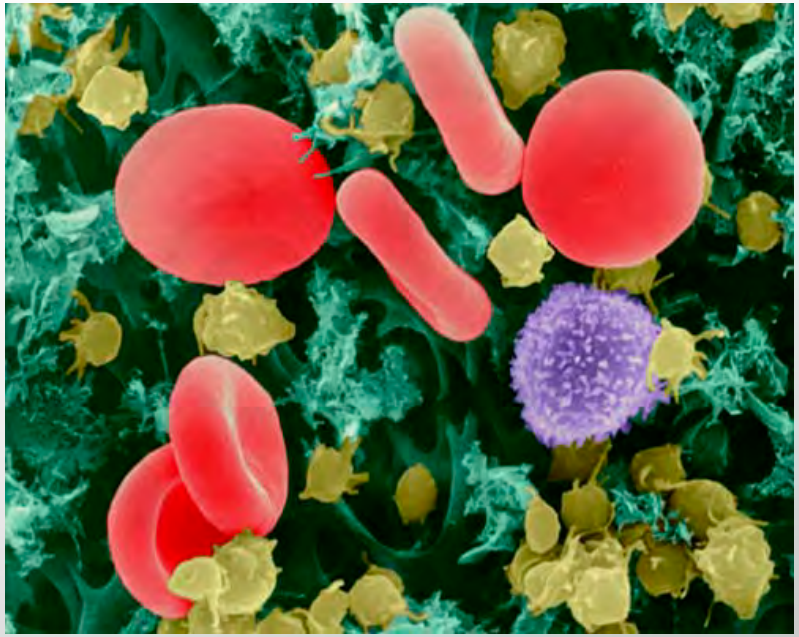


PATHOGENS – CONT'D

- CHALLENGES ASSOCIATED WITH DETECTING AND REGULATING PATHOGENS
- THE INTESTINES OF ALL WARM-BLOODED ANIMALS CONTAIN LARGE NUMBERS OF NON-PATHOGENIC BACTERIAL SPECIES INCLUDING E. COLI, ENTEROCOCCI, BACTERIOIDES, AND MANY OTHERS
- THE INTESTINES MAY ALSO CONTAIN PATHOGENS
- HOWEVER, SPECIFIC PATHOGEN OCCURRENCE IS RELATIVELY RARE WITH LESS THAN A FEW PERCENT OF THE POPULATION INFECTED AT ANY GIVEN TIME
- SPECIFIC PATHOGENS ARE EXCRETED IN THE FECES OF INFECTED INDIVIDUALS FOR A RELATIVELY SHORT TIME PERIOD, DAYS TO WEEKS
- WHETHER A MICROORGANISM IS PATHOGENIC OR NOT IS DETERMINED AT THE SPECIES LEVEL (E.G., NOT ALL FORMS OF E. COLI ARE PATHOGENIC)

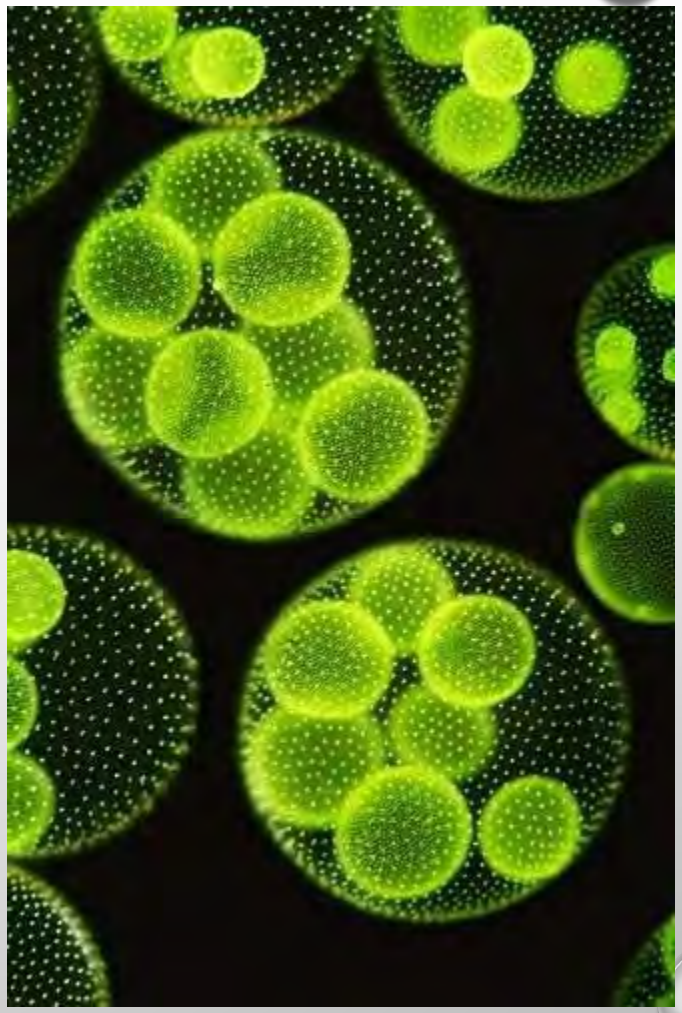
PATHOGENS – CONT'D

- ANALYSIS AND DETECTION OF SPECIFIC PATHOGENS IN WATER IS NOT STRAIGHT-FORWARD AND REQUIRES A HIGHER LEVEL OF ANALYSIS COMPARED ANALYSIS AND DETECTION OF ORGANIC AND INORGANIC CHEMICALS:
  - REVERSE TRANSCRIPTION POLYMERASE CHAIN REACTION (RT-PCR)
  - QUANTITATIVE POLYMERASE CHAIN REACTION (QPCR)
- PATHOGENS DO NOT HAVE CAS NUMBERS
- *"…THE DETECTION OF PATHOGENIC MICROORGANISMS IS NOT NORMALLY ASSOCIATED WITH THE INDICATOR CONCEPT, AS EACH PATHOGEN ESSENTIALLY REPRESENTS ONLY ITSELF AND ITS ABSENCE IS NOT AN INDICATION OF THE ABSENCE OF OTHER PATHOGENS."* WORLD HEALTH ORGANIZATION, 2003



PATHOGENS – CONT'D

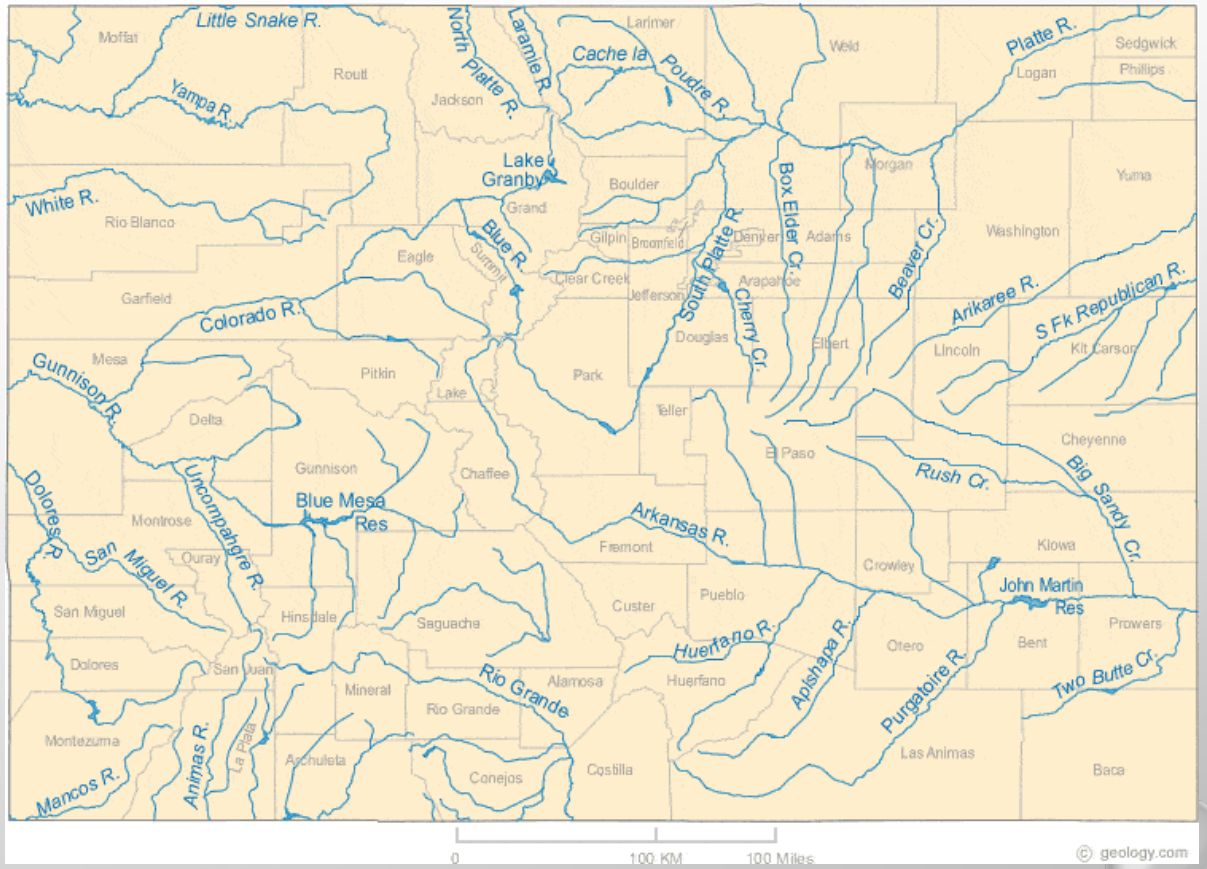
- USEPA THEREFORE REGULATES INDICATORS OF PATHOGENS BASED ON PERCENT REDUCTION DURING TREATMENT OF PUBLIC WATER SUPPLIES.
- REGULATED PATHOGEN INDICATORS:
  - CRYPTOSPORIDIUM, GIARDIA LAMBLIA, LEGIONELLA, VIRUSES (ENTERIC): DRINKING WATER SYSTEMS USING SURFACE WATER OR GROUND WATER UNDER THE DIRECT INFLUENCE OF SURFACE WATER MUST DISINFECT AND FILTER THEIR WATER SO THAT 99 PERCENT OF THESE PATHOGENS ARE REMOVED OR INACTIVATED (KILLED).
  - TOTAL COLIFORMS: NO MORE THAN 5.0% SAMPLES TOTAL COLIFORM-POSITIVE IN A MONTH. EVERY SAMPLE THAT HAS TOTAL COLIFORM MUST BE ANALYZED FOR EITHER FECAL COLIFORMS OR E. COLI IF TWO CONSECUTIVE TC-POSITIVE SAMPLES, AND ONE IS ALSO POSITIVE FOR E.COLI FECAL COLIFORMS, SYSTEM HAS AN ACUTE MCL VIOLATION.



SURFACE WATER QUALITY FRAMEWORK

WQCC IS CHARGED WITH:

- CLASSIFYING STATE SURFACE WATERS BASED ON USE.
- ESTABLISHING AN "ANTIDEGRADATION" RULE FOR SURFACE WATER QUALITY.
- ASSIGNING WATER QUALITY STANDARDS FOR EACH SURFACE WATER BASED ON USE CLASSIFICATION AND ANTIDEGRADATION.
- GRANTING TEMPORARY MODIFICATIONS.
- INTENT IS TO MAINTAIN AND IMPROVE THE QUALITY OF STATE SURFACE WATER.
- INSURE THE SUITABILITY OF CO WATERS FOR BENEFICIAL USES.



DRINKING WATER STANDARDS

Water Quality Parameter	Drinking Water Standard[1]	Groundwater Domestic Use[2]	Surface Water Domestic Use[3]
pH	6.5 – 8.5	6.5 – 8.5	5.0 – 9.0
TDS (mg/L)	500	500	--
Dissolved Oxygen (mg/L)	--	--	3.0
F. Coli / E. Coli (cells/ 100 mL)	Absent	2.2 (30 day avg)	630
Nitrate (mg/L)	10	10	10
Chloride (mg/L)	250	250	250
Sulfate (mg/L)	250	250	250
Iron (mg/L)	0.3	0.3	--
Lead (mg/L)	0.00	0.05	--
Arsenic (mg/L)	0.01	0.01	0.1

[1] WQCC Regulation No. 11 – Colorado Primary Drinking Water Standards.
[2] WQCC Regulation No. 41 – The Basic Standards for Groundwater.
[3] WQCC Regulation No. 31 – The Basic Standards for Surface Water.
NOTE: This information is being provided for educational purposes only, it is incomplete, and should not be used for anything other than this presentation.

COMPARISON OF WATER STANDARDS FOR DIFFERENT USES

Water Quality Parameter	Drinking Water Standard[1]	Groundwater Agricultural Use[2]	Surface Water Aquatic Life[3]
pH	6.5 – 8.5	6.5 – 8.5	6.5 – 9.0
TDS (mg/L)	500	Depends on BG	--
Dissolved Oxygen (mg/L)	--	--	5.0 – 7.0
F. Coli / E. Coli (cells/ 100 mL)	Absent	--	--
Nitrate (mg/L)	10	100	--
Chloride (mg/L)	250	--	--
Sulfate (mg/L)	250	--	--
Iron (mg/L)	0.3	5	1.0 (chronic)
Lead (mg/L)	0.015	0.1	Calculated[4]
Arsenic (mg/L)	0.01	0.1	0.15 – 0.34

[1] WQCC Regulation No. 11 – Colorado Primary Drinking Water Standards.
[2] WQCC Regulation No. 41 – The Basic Standards for Groundwater.
[3] WQCC Regulation No. 31 – The Basic Standards for Surface Water.
[4] Calculated based on hardness.
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COMPARISON OF WATER STANDARDS FROM DIFFERENT SOURCES

Water Quality Parameter	Upper South Platte R Segment 6b Chatfield Reservoir	Upper South Platte R Segment 16d Second Creek	Clear Creek Segment 7 Woods Creek	Clear Creek Segment 8 Lion Creek
State Use Classification	Aquatic Life (Cold), Recreation 1a, Water Supply, Agriculture	Aquatic Life (Warm), Recreation 1a, Water Supply, Agriculture	Aquatic Life (Cold), Recreation 2	Aquatic Life (Cold), Recreation 1a
pH	6.5 – 9.0	6.5 – 9.0	6.0 – 9.0	3.0 – 9.0
TDS (mg/L)	--	--	--	--
Dissolved Oxygen (mg/L)	6.0	3.3	6.0	6.0
F. Coli / E. Coli (cells/ 100 mL)	200 / 126	200 / 126	2000 / 630	200 / 126
Nitrate (mg/L)	10	--	--	--
Chloride (mg/L)	250	--	--	--
Arsenic (mg/L)	0.05	0.1	--	--

WQCC Regulation No. 38 – Classifications and Numeric Standards South Platte River Basin, Laramie River Basin, Republican River Basin, Smoky Hill River Basin.
Aquatic Life (Cold) – Currently or potentially capable of sustaining a wide variety of cold water biota, including sensitive species.
Aquatic Life (Warm) – Currently or potentially capable of sustaining a wide variety of warm water biota, including sensitive species.
Recreation 1 – Existing primary contact use.
Recreation 2 – Potential primary contact use.
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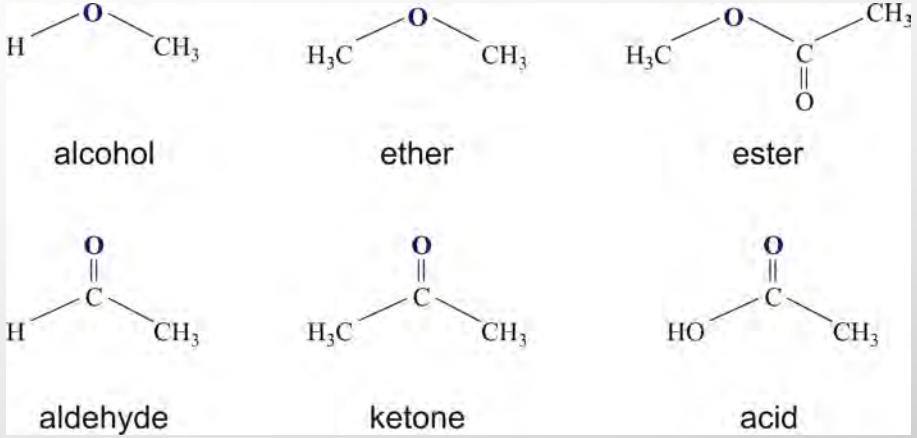
OTHER WATER QUALITY INDICATORS

- ORGANIC CHEMICALS
- DISINFECTANTS AND DISINFECTION BYPRODUCTS
- ASBESTOS
- RADIONUCLIDES
- CYANIDE AND RELATED COMPOUNDS
- PFAS – THE NEW KID ON THE BLOCK

ORGANIC CHEMICALS

- THERE ARE 1,000S OF ORGANIC CHEMICALS THAT CAN BE DISSOLVED IN WATER
- MANY ORGANIC CHEMICALS ARE TOXIC TO HUMANS, AQUATIC LIFE, AND CROPS IF PRESENT AT SUFFICIENT LEVELS
- EPA AND THE WQCC HAVE LISTS OF SPECIFIC ORGANIC CONTAMINANTS WITH PROMULGATED MCLS
- TYPICALLY ORGANIC CHEMICALS ARE PRESENT IN WATER AT SUB-PPM LEVELS
- MANY MCLS FOR ORGANIC CHEMICALS ARE IN THE PART-PER-BILLION RANGE
- EXAMPLE: BENZENE MCL = 0.005 MG/L



ORGANIC CHEMICALS – CONT'D

HYDROCARBONS
- ALKANES, ALKENES, ALKYNES
- CYCLOALKANES
- ORGANIC ACIDS
- AROMATIC HYDROCARBONS
- POLYAROMATIC HYDROCARBONS

SOLVENTS
- NONHALOGENATED SOLVENTS
  - KETONES
  - GLYCOLS
  - ETHERS
  - AMINES
  - GLYCOL ETHERS
  - NITROPARAFFINS
  - FURANS
  - NITRILES
  - ALCOHOLS AND ESTERS
- HALOGENATED SOLVENTS

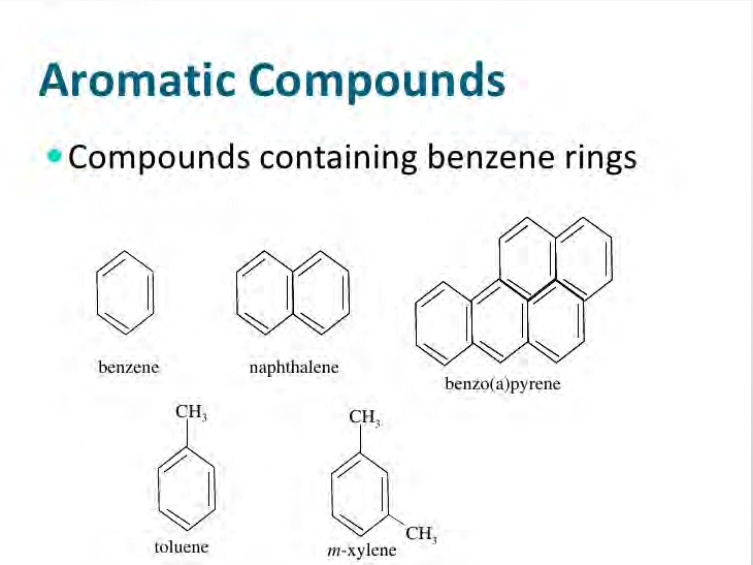
Pesticides
- Insecticides
- Herbicides
- Fungicides
- Soil Fumigants

Industrial Intermediates
- Phthalate Esters
- Chlorobenzenes
- Chlorophenols

Explosives
- Aliphatic Nitrate Esters
- Nitramines
- Primary explosives

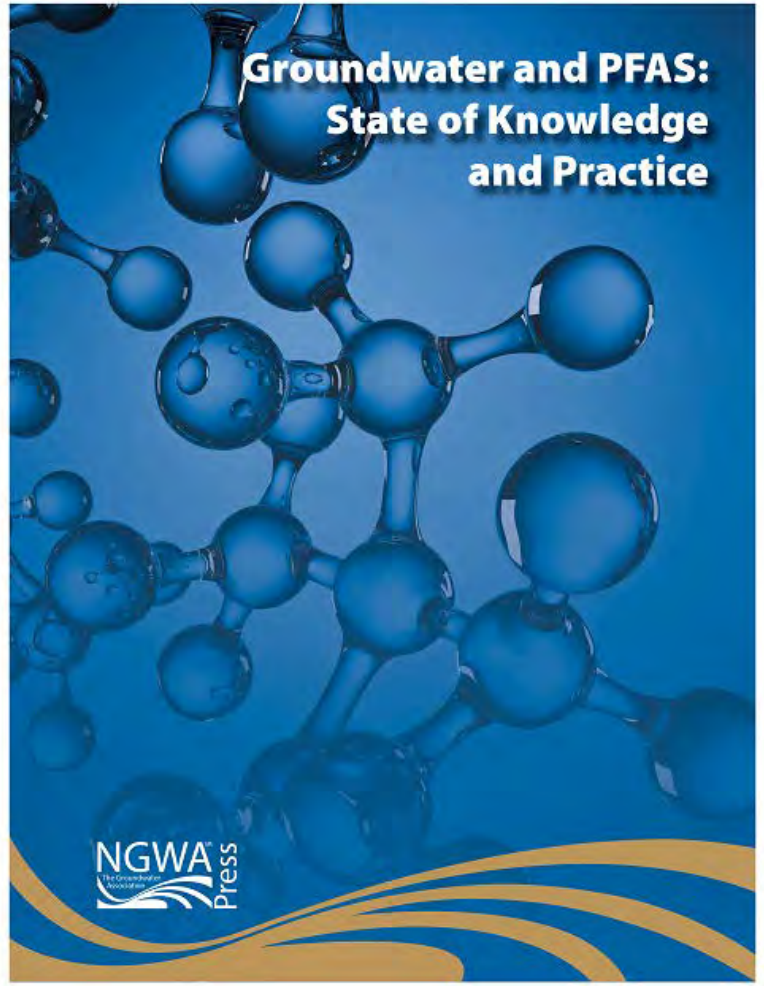
Polychlorinated Biphenyls (PCBs)

Dioxins and Furans



PFAS – THE NEW KIDS ON THE BLOCK

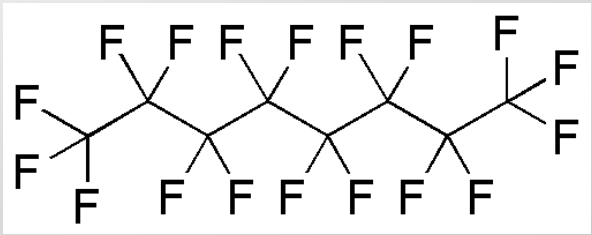
- THERE IS A NEW CLASS OF ORGANIC CHEMICALS THAT IS RECEIVING MUCH REGULATORY ATTENTION
- PER- AND POLYFLUOROALKYL SUBSTANCES (PFAS)
- THERE ARE OVER 3,000 INDIVIDUAL PFAS CHEMICALS
- EPA RECENTLY ISSUED HEALTH ADVISORIES FOR TWO PFAS CHEMICALS:
  - PFOS
  - PFOA
  - BOTH WERE COMMONLY USED IN AQUEOUS FIRE FIGHTING FOAMS (AFFFS)
  - EPA'S HEALTH ADVISORY LEVELS FOR PFOS AND PFOA ARE 70 PARTS PER TRILLION (PPT)



PFAS – THE NEW KIDS ON THE BLOCK

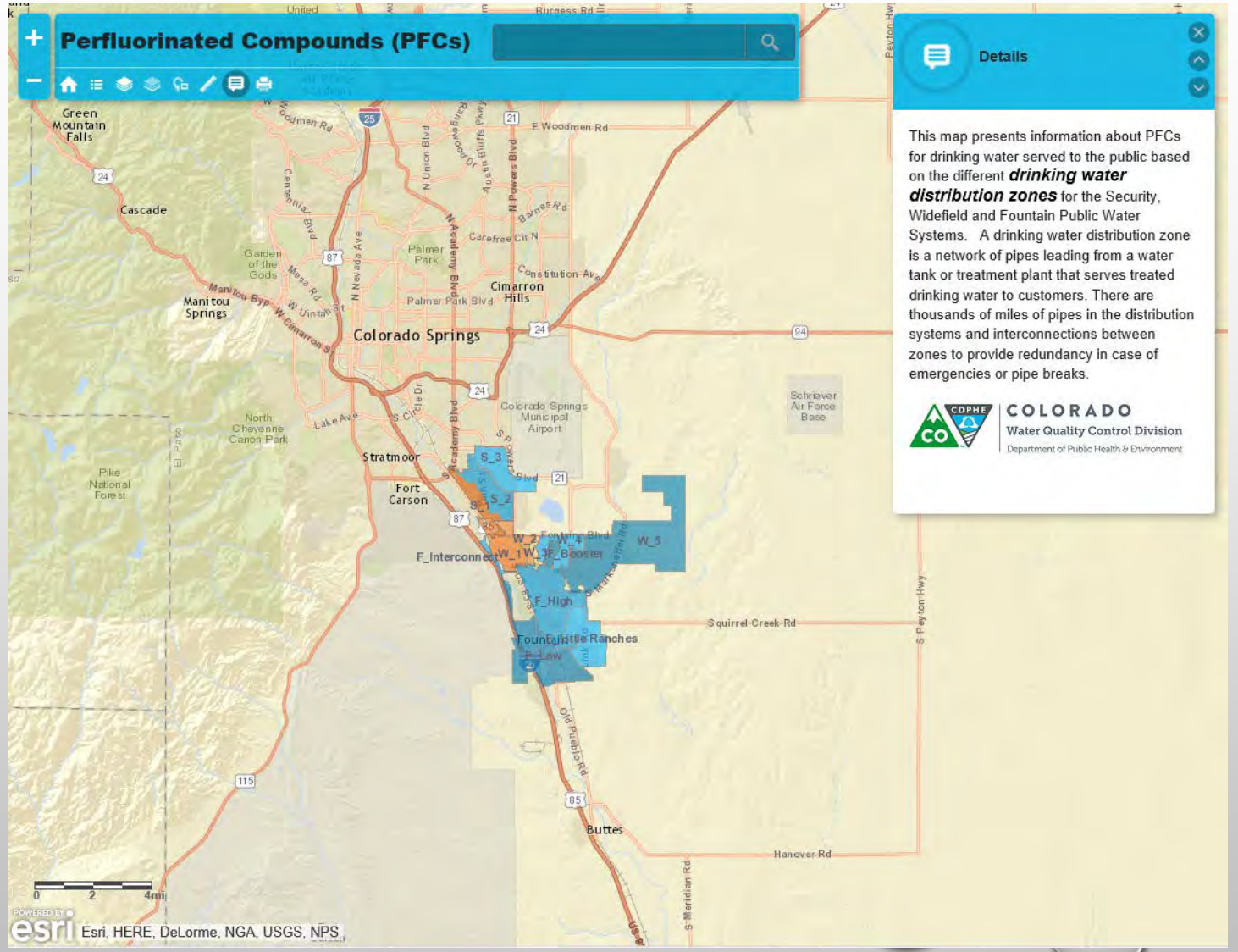
- FLUORINE HAS SEVERAL DISTINCT CHEMICAL DIFFERENCES FROM ALL OTHER SUBSTANCES ENCOUNTERED IN ORGANIC CHEMISTRY:
- C-F BOND IS THE STRONGEST BOND IN ORGANIC CHEMISTRY.
- THE FLUORINE ATOMS EFFECTIVELY "SHIELD" THE C-C BONDS.
- HIGH THERMAL AND CHEMICAL STABILITY (STABLE IN ACIDS, BASES, OXIDANTS, AND HEAT).
- RESISTANT TO MICROBIAL DEGRADATION.
- SIMULTANEOUSLY HYDROPHOBIC AND LIPOPHOBIC.

Carbon Tetraflouride



Perfluorooctane

PFAS IN COLORADO



WATER QUALITY PREFERENCES BY BENEFICIAL USE

Water Quality Parameter	Preferred Range for Fish Culture1	Hydraulic Fracturing Fluids	Laboratory Grade Water	Semiconductor Manufacturing
pH	6 – 8	6 - 8	5 – 8	5 - 7
TDS (mg/L)	--	1,500 – 7,700	--	<0.01
Dissolved Oxygen (mg/L)	>4	--	--	0.001
Ammonia (mg/L)	<0.02	38.5	--	0.0001
Alkalinity (mg/L)	50 – 300	< 300	--	< 0.001
Hardness (mg/L)	>50	Low	--	<0.001
Iron (mg/L)	<0.02	< 10	--	0.00005
Chloride (mg/L)	--	126 – 2790	< 0.05	0.0001
Sulfate (mg/L)	--	35 – 162	--	0.0001
Sodium (mg/L)	--	95 – 793	< 0.05	0.00005
Bacteria	--	None	None	None