Cartwright Consulting Co., LLC

www.cartwright-consulting.com
pscartwright@msn.com

United States Office
8324 16th Avenue South
Minneapolis, MN 55425-1742
Phone: (952) 854-4911
Fax: (952) 854-6964

European Office
President Kennedylaan 94
2343 GT Oegstgeest
The Netherlands
Phone: 31-71-5154417

Groundwater Contaminants – What Does the Future Hold?

by

Peter S. Cartwright, PE

Presented at:
NGWA 2017 Groundwater Summit

December 6, 2017

Groundwater Supply

Total Global Groundwater Volume = 23 x 10^6 kilometers (6 x 10^{18} gallons)

Of that, 0.35 x 106 kilometers (9 x 1010 gallons) is < 50 years old (1½%)

Science Daily, 16 Nov, 2015

Domestic Well Water

- Supplies 15% of the U.S. population
- Not covered by U.S. EPA Safe Drinking Water Regulations

Water-Borne Contaminants

Water Contaminants

Class	Examples
Suspended solids	Dirt, clay, colloidal materials, silt, dust, insoluble metal oxides and hydroxides
Dissolved organics	Trihalomethanes, synthetic organic chemicals, humic acids, fulvic acids
Dissolved ionics (salts)	Heavy metals, silica, arsenic, nitrate, chlorides, sulfates
Microorganisms	Bacteria, viruses, protozoan cysts, fungi, algae, molds, yeast cells
Gases	Hydrogen sulfide, methane, radon, carbon dioxide

U.S. EPA lists drinking water contaminants by two standards:

- Primary – Health Related
- Secondary – Mainly Aesthetic Related
- Maximum Contaminant Level (MCL).
- Usually in mg/L (ppm) or µg/L (ppb).
- New MCLs starting to be listed in ppt concentrations (1 second in ~ 32,000 years).

Primary drinking water standards constantly evolving – virtually always getting tighter

A Case and Point - Manganese

- Used to be considered only aesthetic issue (staining).
- EPA Secondary Standard – 0.05 ppm (mg/L)
- Now health concerns (MCL not determined)

USGS Study of Domestic Wells (1991-2004) (Circular 1332)

- 2100 private wells
- 48 states
- 30 regionally extensive aquifers

Findings:

- 23% - at least one contaminant above MCL – U.S. EPA Primary Drinking Water Standard
- 60% - organic compounds (herbicides, pesticides, etc.) Low concentrations (PPCPs)
- 34% - coliform bacteria
- 48% - at least one contaminant above MCL – U.S. EPA Secondary Drinking Water Standard

Inorganic Ions

- Sodium
- Calcium
- Magnesium
- Strontium
- Boron
- Iron
- Manganese
- Arsenic
- Uranium
- Fluoride
- Nitrate
- Chloride
- Sulfate

Organic Compounds

- Pesticides
- Herbicides
- Volatile organics (benzene, chloroform, etc.)
- Tannins
- Fulvic Acid

NGWA – currently 12 BSP documents - Best Suggested Practices – addressing water-borne contaminants

These Cover:

- Iron and Manganese
- Strontium
- Boron
- Arsenic
- Uranium
- Fluoride
- PFAS (new)
- Nitrate
- Perchlorate
- Radon
- Methane
- Hydrogen Sulfide
- Microorganisms

Arsenic

- Naturally occurring
- Hotspots:
  - New England
  - Upper Midwest
  - South West
  - Southern Texas
- ~ 2 million people exposed to high levels

Lead is a metal that occurs naturally in the environment

=

It is poisonous to humans and animals when consumed.

The presence of lead in groundwater tends to be very small – almost undetectable.

A greater concern is the presence of lead in:

- Galvanized steel pipes
- Certain brass used in plumbing fittings and fixtures, or well components
- Certain solder used to connect pipes and joints

Microorganisms

Categories of Microorganisms

- Bacteria
- Protozoa
- Viruses

Microorganisms that can cause disease in humans are known as PATHOGENS

Microorganisms

(CDC 2011-12) >50% of water-borne outbreaks from groundwater

Minnesota Department of Health Virus Study

- Similar occurrences between community and private wells
- 36+% system occurrence rate for the enteric viruses
- Wells previously thought not vulnerable appear to be susceptible to virus contamination

PPCPs

Also Known As:

- CECs (contaminants of emerging concern)
- EPOCs (emerging pollutants of concern)
- EPPPs (environmental persistent pharmaceutical pollutants)
- APIs (active pharmaceutical ingredients)
- EDCs (endocrine disrupting chemicals [compounds])

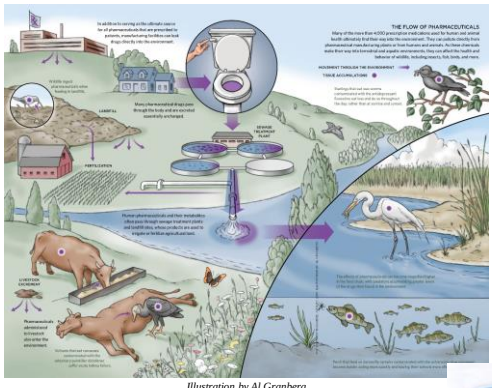


Illustration by Al Granberg

PPCPs (Pharmaceutical and Personal Care Products)

- Unmetabolized drugs (in urine, feces)
- Discarded pharmaceutical products
- Cosmetics
- Virtually every chemical flushed down the drain – mostly organic and non-biodegradable

EDCs (Endocrine Disrupting Chemicals)

Agents that interfere with the synthesis, secretion, transport, binding or elimination of natural hormones in the body

Responsible for maintenance of homeostasis, reproduction, development and behavior

Concentrations in Drinking Water

parts per trillion (ppt)

1 ppt =

1 second in ~32,000 years

6” leap in journey to the sun

Pinch of salt in 10,000 tons of potato chips

PPCPs Are Mostly Organic Chemicals

- Estimated 80,000-100,000
- Virtually all human-made

Perfluorinated Compounds (PFCs)

- Also known as PFAS – polyfluoroalkyl substances
- Large family of fluorine – containing organic compounds
- Very resistant to biodegradation
- Affect immune system development in fetuses

Examples

- Perflurooctanic Acid (PFOA) – Teflon®
- Perfluorooctane Sulfonate (PFOS) - Scotchgard®

New NGWA BSP

"Groundwater and PFAS: State of Knowledge and Practice"

PPCPs

1) Are the concentrations increasing?
2) Do the current concentrations have any effect on human health?

As population increases, PPCP concentrations increasing

Are any of these contaminants in such tiny concentrations a risk?

PPCP Health Effects?

- Last 30 years, birthrate for males declined every year
- Reproductive organ abnormalities increased 200% over last 20 years
- 85% of sperm DNA in healthy males damaged
- 300% increase in testicular cancer

Particles

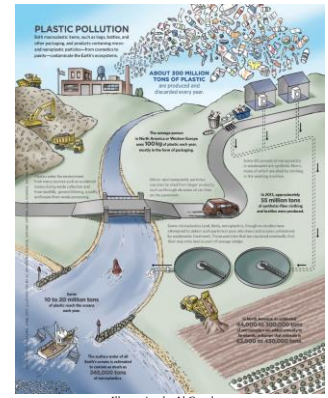


Illustration by Al Granberg

Nanoparticles

Insoluble materials generally in size range of nanometers (10^{-9} meter)

Also Known As:

- Microfibers
- Nanofibers
- Microplastics
- Nanomaterials
- Nanoplastics

Nanofibers

- Fabric finishes
- Antifouling paints
- Degradation byproducts

Examples

- Cosmetic beads
- Lint
- Fleece fragments

Yet to be Determined:

- Long term effects of exposure to PPCPs & particles
- New chemicals resulting from mixtures of PPCPs
- Effects on the immunocompromised
- PPCP effects on bacteria, fungal and aquatic life
- Effects on antibiotic resistance

No Link of PPCPs and Nanoparticles to Human Health YET

- **Many studies underway**
- **No link identified yet**
- **Opinion – only a matter of time**

Treatment for Contaminant Reduction

No Single Treatment Technology

Multibarrier approach is required

Optimum Technology Depends Upon:

- Contaminant Chemistry
- Concentrations
- Potential Effect (Health, Aesthetic, etc.)
- Degree of Removal Requirement
- Economics

Treatment Locations

POE – Point of Entry
POU – Point of Use

Treatment Summary

Contaminant	POE TREATMENT CHOICES			POU TREATMENT CHOICES		
Iron (Fe)	Oxidation/Filtration	IX	Softening	None	-----	-----
Manganese (Mn)	Oxidation/Filtration	IX	Softening	None	-----	-----
Strontium (Sr)	RO/Filtration	IX	-----	RO	IX	Distillation
Lead (Pb)	RO	IX	Replace Components	RO	IX	Distillation
Boron (B)	RO/Filtration	IX	-----	RO	IX	Distillation
Arsenic (As)	RO*	IX*	Adsorptive Media	RO*	IX*	Adsorptive Media
Uranium (U)	RO	IX	-----	RO	IX	Distillation
Fluoride (F)	RO	IX	Adsorptive Media	RO	IX	Distillation
Nitrate (NO_3)	RO	IX	-----	RO	IX	Distillation
Perchlorate (ClO_4)	RO	IX	-----	RO	IX	Distillation
Radon (Rn)	Aeration	-----	-----	-----	-----	-----
Methane (CH_4)	Aeration	-----	-----	-----	-----	-----
Hydrogen Sulfide (H_2S)	Aeration	AC	Oxidation	-----	AC	Oxidation
Microorganisms	Disinfection	-----	-----	Ozonation	UF	UV

** Following oxidation*
RO = Reverse Osmosis
IX = Ion Exchange
AC = Activated Carbon

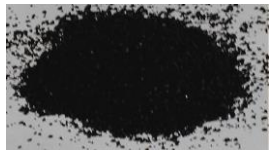
PPCP Removal Technologies

Treatment Technologies	Molecular Weight of Organic (Daltons)	Other Removal Characteristics
Activated Carbon	------	Primarily, more aromatic organics are adsorbed
Microfiltration	>100,000	Removes most particles
Ultrafiltration	>10,000	Removes most particles
Nanofiltration	>400	Virtually all particles and most multivalent ionic salts
Reverse Osmosis	>100	Almost all ionic salts removed as well as particles

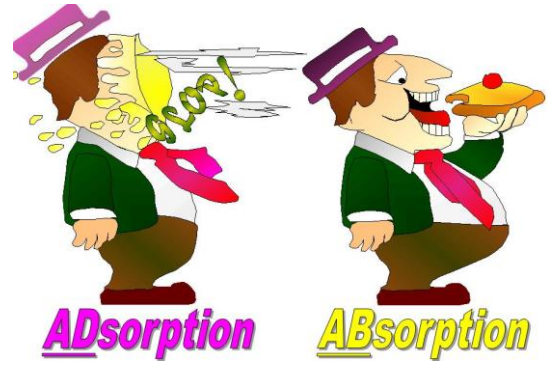
Adsorption with Activated Carbon

Low Molecular Weight
Relatively Volatile Organics

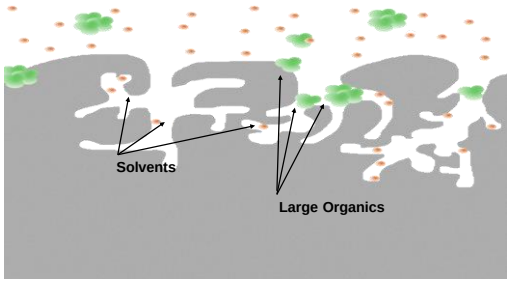
Activated Carbon



- Absorption - a substance penetrating into the carbon
- Adsorption - a substance adhering to the surface of the carbon



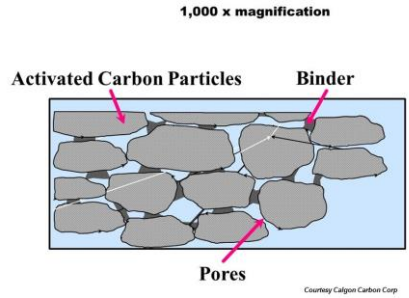
Activated Carbon Structure



Carbon Types

Bituminous
Lignite
Wood
Coconut Shell

Carbon Block

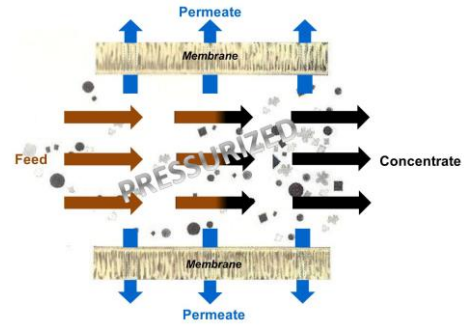


Membrane Technologies

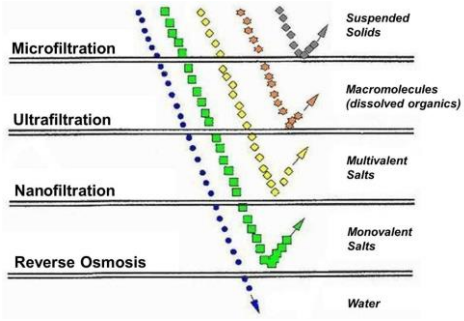
Membrane Filtration

Microfiltration
Ultrafiltration
Nanofiltration
Reverse Osmosis

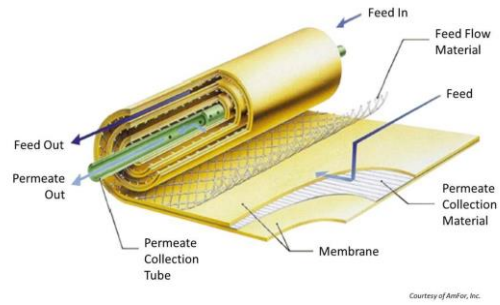
Membrane Process



Membrane Technologies

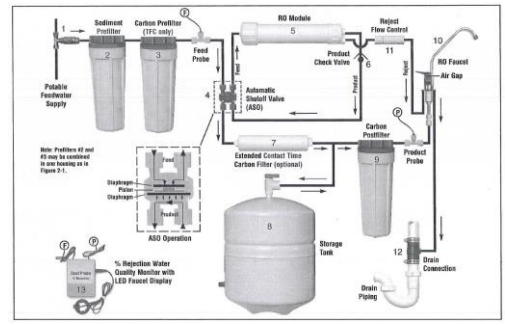


Spiral Wound Membrane



POU Reverse Osmosis Unit Components

POU RO System



Normal POU RO System

- Softening (hardness)
- Filtration (sediment)
- GAC (chlorine) for TFC membranes

Advanced Oxidation Processes (AOPs)

Ozone
Ozone/H_2O_2
Ozone/UV
UV/TiO_2
UV/H_2O_2
Hydroxyl Radical (•OH)

AOPs

- Break Chemical Bonds
- Form More Easily Treated (or less harmful) Compounds

Ozone

- Best disinfectant
- Strong oxidant
- Destroys biofilms (slowly)
- Dissipates, converts to O_2
- Very little rinsing required
- Test strips or test kit to monitor

Ion Exchange Technology

- Uses resins to adsorb ions (lead, manganese, hardness, etc.)
- Regenerated onsite

Contact Information

Peter S. Cartwright, PE

peterscartwright@gmail.com

www.cartwright-consulting.com

952-854-4911