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NGWA 2015 Groundwater Expo

Compromised Water Quality – Challenges and Solutions

by

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Introduction

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Groundwater Supply

Total Global Groundwater Volume =
23×10^{6} kilometers (6×10^{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

USGS National Water-Quality Assessment Program

23% of sampled domestic wells had one or more health-related contaminant above the MCL

Contaminants
80% naturally occurring (e.g. manganese, arsenic, radon)
20% human source (e.g. nitrates, solvents, pesticides)

(Circular 1332) 1991-2004

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Water-Borne Contaminants

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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

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Inorganic Ions

- Arsenic
- Strontium
- Boron
- Iron
- Manganese
- Uranium
- Fluoride
- Nitrate

Organic Compounds

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

Dissolved Gases

- CO_2
  - In air
  - Reacts with water to form carbonic acid (H_2CO_3)
  - Corrosive to metal, will form scale if heated in water containing calcium/magnesium
- O_2
  - In air
  - No reaction with water
  - Pitting in metal, especially when heated

Dissolved Gases (cont.)

- **H_2S**
  - Produced by anaerobic bioremediation
  - May react with water, depending on pH (H2SO4)
  - Strong odor – inhalation hazard
  - Black stains on plumbing
  - Explosive hazard
  - Can cause corrosion
- **Methane**
  - Produced by anaerobic bioremediation
  - Explosion hazard
- **Radon**
  - Naturally occurring gas
  - Health hazard (can cause lung cancer)

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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 ~ 35,000 years).

Primary drinking water standards constantly evolving – virtually always getting tighter

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

These Cover:

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

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Treatment for Contaminant Reduction

Optimum Technology Depends Upon:

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

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Treatment Locations

POE – Point of Entry

POU – Point of Use

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Treatment Summary

Contaminant	Chemical Form	POE TREATMENT CHOICES			POU TREATMENT CHOICES		
Iron (Fe)	Cation	Oxidation/Filtration	IX	Softening	None	-----	-----
Manganese (Mn)	Cation	Oxidation/Filtration	IX	Softening	None	-----	-----
Strontium (Sr)	Cation	RO/Filtration	IX	-----	RO	IX	Distillation
Boron (B)	Anion	RO/Filtration	IX	-----	RO	IX	Distillation
Arsenic (As)	Anion	RO*	IX*	Adsorptive Media	RO*	IX*	Adsorptive Media
Uranium (U)	Anion	RO	IX	-----	RO	IX	Distillation
Fluoride (F)	Anion	RO	IX	Adsorptive Media	RO	IX	Distillation
Nitrate (NO_3)	Anion	RO	IX	-----	RO	IX	Distillation
Perchlorate (ClO_4)	Anion	RO	IX	-----	RO	IX	Distillation
Radon (Rn)	Gas	Aeration	-----	-----	-----	-----	-----
Methane (CH_3)	Gas	Aeration	-----	-----	-----	-----	-----
Hydrogen Sulfide (H_2S)	Gas	Aeration	AC**	Oxidation	-----	AC**	Oxidation
Microorganisms	Suspended Solids	Disinfection	-----	-----	Distillation	-----	-----

** Following oxidation*

RO = Reverse Osmosis

IX = Ion Exchange

AC = Activated Carbon

Specific Examples

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Almost All Problems Result from More Than One Contaminant

HARDNESS

(Not yet covered by BSP)

Generally scale formed by insoluble carbonates of calcium and magnesium

- Hardness causes scaling inside piping, on the discharge surfaces of shower fixtures, faucets, etc.
- Also cause soap “scum” in bath tubs, spotting/discoloration of laundry and other aesthetic effects.
- Economic effects: more soap, higher heater costs, more water usage.

- Many groundwater supplies saturated in hardness.
- Any evaporation will cause scaling.

Hardness

Dishwasher

Heating Element

Piping

Shower Fixture

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Copper Pipe Leakage

500 ppm Hardness

Courtesy of: Greg Reyneke www.gregknowswater.com

Pinhole Leak

1500 ppm Hardness / 300 ppm Sulfate

Courtesy of: Greg Reyneke www.gregknowswater.com

Tank Level Float

6840 ppm Hardness / 3 ppm Iron IRB

Courtesy of: Greg Reyneke www.gregknowswater.com

Treatment for Hardness

- Softening (Sodium ion Exchange
- pH Adjustment
- Chemical Addition

All POE

IRON (Fe)

Iron in wells is the soluble, colorless, Fe^{+2} form.

Contact with air (oxygen) oxidizes it to the Fe^{+3} form – insoluble $Fe(OH)_3$ form – reddish brown precipitate

Iron

- Stain fixtures (sinks, toilets, etc.)
- Stain laundry
- Give water a “metallic taste”

Iron

Concentrations >0.3 ppm cause staining

Iron

May also be present as:

- Bacteria iron formed by iron-reducing bacteria (IRB)
- Combined with organics (“heme” iron)

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Iron

Faucet

Bath Tub

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Iron

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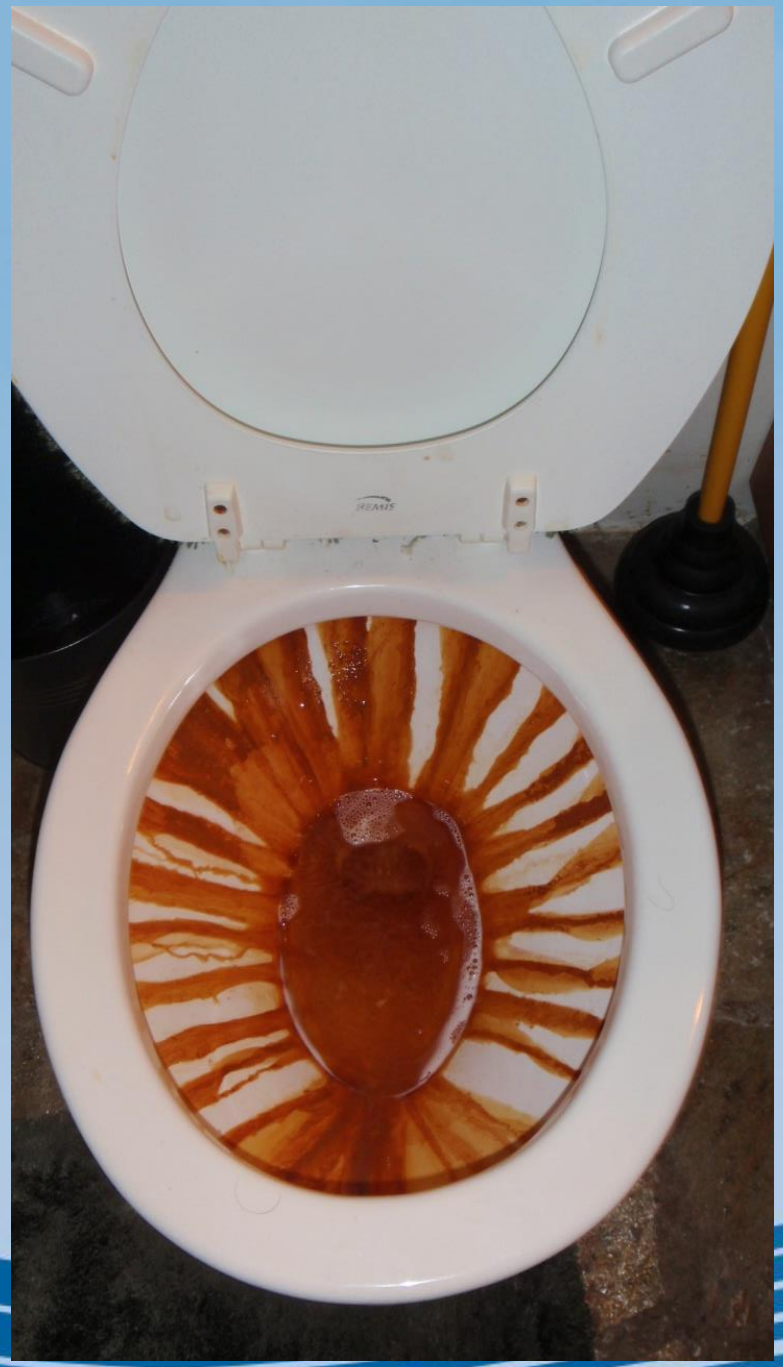


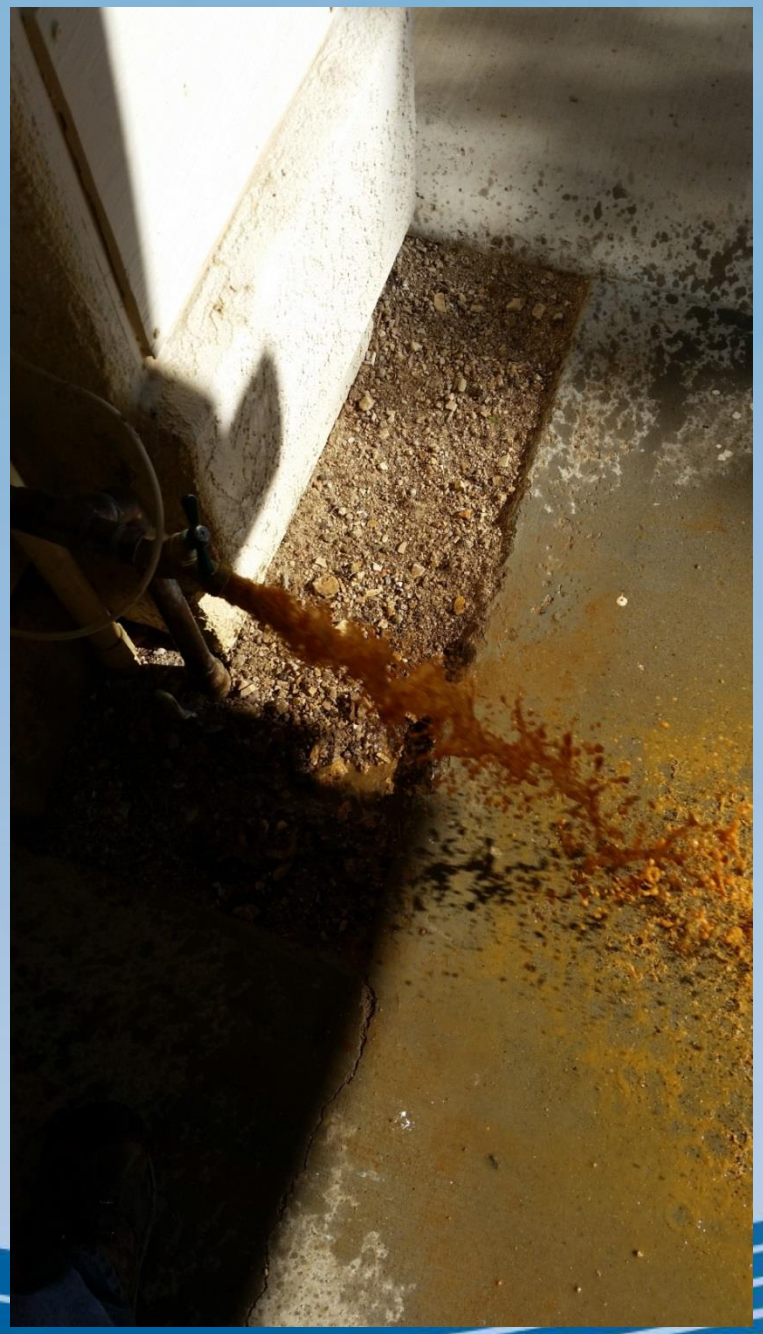
Toilet

15 ppm Ferric Iron

Courtesy of: Greg Reyneke www.gregknowswater.com

Storage Tank

8 ppm Ferric Iron



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Treatment for Iron

- Oxidation/filtration (Mn Greensand)
- Softening (Low iron concentration)

MANGANESE (Mn)

- Usually present with iron in groundwater
- Oxidized to the insoluble state (not as easily as iron)
- Forms black precipitate
- EPA considering putting manganese on Primary List

Manganese

- Causes similar staining problems as iron

Bath Tub

Filter Cartridge Manganese

Courtesy of: Greg Reyneke www.gregknowswater.com

Manganese

Concentrations > 0.05 ppm cause staining

Treatment for Manganese

- Oxidation/filtration (Mn Greensand)
- Softening (low manganese concentration

ARSENIC

- Odorless, colorless, tasteless in water
- Poisonous, a primary contaminant on the EPA Safe Drinking Water list
- MCL (Maximum Contaminant Level) = 10 ppb (0.010 ppm)
- Chemically classified as a “semi-metal” element

Arsenic

- In water supplies usually as As(III) or as As (V)
- Can also form organic compounds – less toxic, less prevalent

Treatment for Arsenic

POE: 1) Special iron-based adsorptive media

2) Oxidize to As(V), add iron,

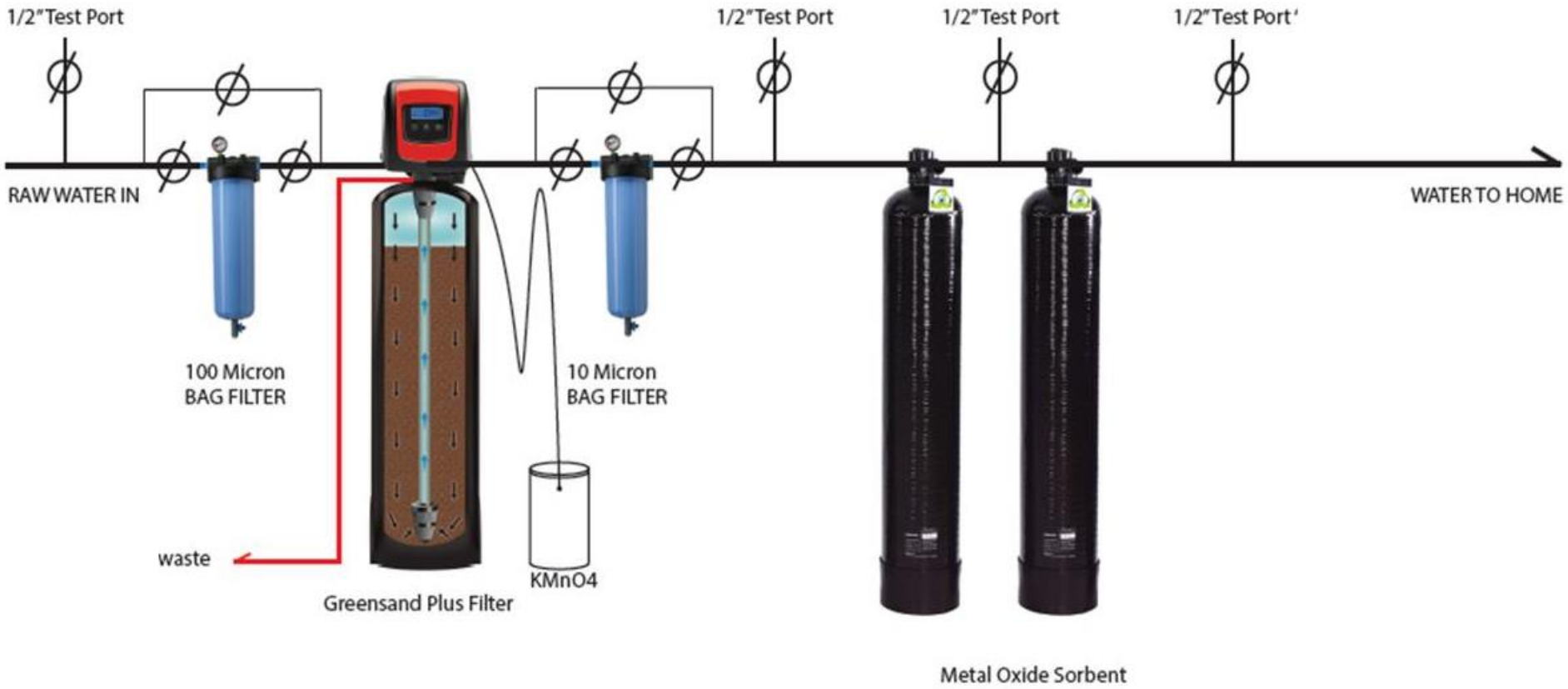
e.g.. $Fe(Cl)_3$, filter

POU: 1) Oxidize to As(V), RO

2) Oxidize to As(V), IX

3) Distillation

Arsenic Removal System



RAW WATER DATA (05/26/2015):
Arsenic - 0.023 mg/L
Iron - 0.119 mg/L
Manganese - 0.070 mg/L
Silica - 28.2 mg/L
Alkalinity - 250 mg/L
pH - 7.6

Courtesy of: Greg Reyneke www.gregknowswater.com

Arsenic Removal System

Courtesy of: Greg Reyneke www.gregknowswater.com

URANIUM

- Naturally occurring, odorless, colorless, tasteless
- Radioactive, primary contaminant on the EPA Safe Drinking Water list
- EPA MCL = 30 ppb (0.030ppm)
- Some states have set lower limits
- Chemically, forms anion in water

Treatment for Uranium

POE: Ion (Anion) Exchange

POU:
1) RO
2) IX
3) Distillation

FLUORIDE

- Naturally occurring, odorless, colorless, tasteless
- Often added to municipal water supplies to minimize incidence of dental cavities
- MCL = 4.0 ppm – currently under review

Treatment for Fluoride

POE: Special adsorbing resins (activated alumina)

POU:
1) RO
2) IX (Anion)
3) Distillation

NITRATE

- Odorless, colorless, tasteless
- Generally result from human activity:
  - Agricultural (fertilizers, animal manure)
  - Septic systems
  - Industrial effluent
- On primary SDWA list
- MCL = 10.0 ppm

Treatment for Nitrate

POE: IX (Anion)

POU:
1) RO
2) IX
3) Distillation

METHANE (CH_4)

- Odorless, colorless gas
- Poisonous gas, extremely flammable
- Produced from anaerobic bacterial activity
- Concentration >10 ppm a danger
- 50,000 ppm concentration explosive

Methane

Treatment for Methane

POE: Aeration

POU: Not applicable

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Aeration

TODAY
TOMORROW

Manufactured by:
WATER GUARD
A Division of Action Mfg. & Supply, Inc.

HYDROGEN SULFIDE (H_2S)

- Colorless, but very pungent gas (rotten egg odor)
- Flammable, explosive and corrosive
- Numerous health effects associated with inhalation
- Produced mainly by sulfate-reducing bacteria (SRB)

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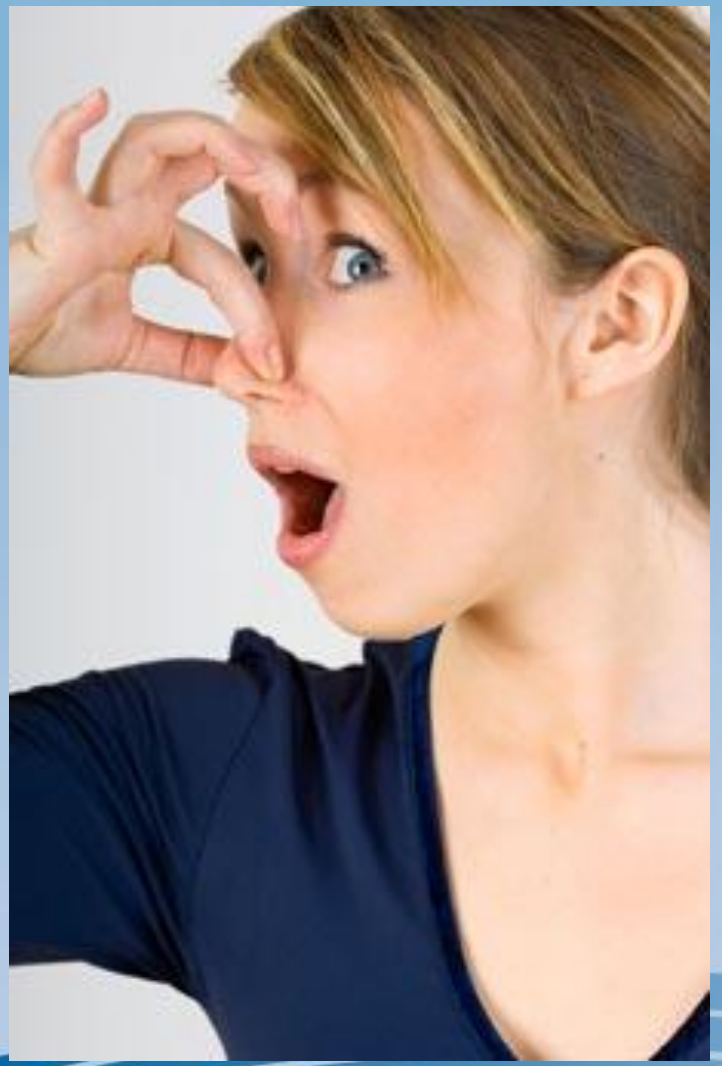
Hydrogen Sulfide



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Hydrogen Sulfide

TODAY TOMORROW

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Storage Tank

H_2S from SRB

Courtesy of: Greg Reyneke www.gregknowswater.com

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Treatment for Hydrogen Sulfide

POE:

1) Aeration
2) Activated Carbon Adsorption
3) Chlorination (bacteria inactivation)
4) IX (Anion)

Filter Cartridge

Sawdust leaked into well

Courtesy of: Greg Reyneke www.gregknowswater.com

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Tannins

- Can cause water to have a faint yellow to tea-like color.
- Can cause yellow staining on fabrics, fixtures, china and laundry.
- May cause water to have a “musty” or “earthy” odor.

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Color

Could be:

- Turbidity, e.g. Silt
- Iron, e.g. Ferric
- Organics, e.g. Tannis

Contact Information

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