Onsite Drinking Water Treatment

Acknowledgement

- Guidance and assistance on development of this presentation was provided by the Texas Groundwater Protection Committee and the Texas Commission on Environmental Quality. The effort was partially funded by the U.S. Environmental Protection Agency

Overview

- Introduction
- Contaminates of concern
  - Public health issues
  - Maximum contaminant level (MCL)
  - Areas of concern
  - Treatment Options
- How to select a treatment unit
- Resources

Introduction

- Groundwater provides a large portion of our drinking water.

- Fifteen percent of Americans have their own sources of drinking water.

- It is up to well owners to ensure their water is safe to drink.

How do Aquifers Become Polluted?

- Aquifers become polluted through
  - Leaching from rocks
  - Pollutants carried down from the surface by percolating water
  - Surface water recharge
  - Interaquifer exchange
  - Direct mitigation

Drinking Water Quality

- EPA rules do not apply to private wells; however, EPA standards are a good basis for determining what your drinking water quality should be.

- MCL - Maximum contaminant level

Water Quality Standards

- National Primary Drinking Water Regulations
  - Protect public health

- National Secondary Drinking Water Regulations
  - Aesthetic or cosmetic effects

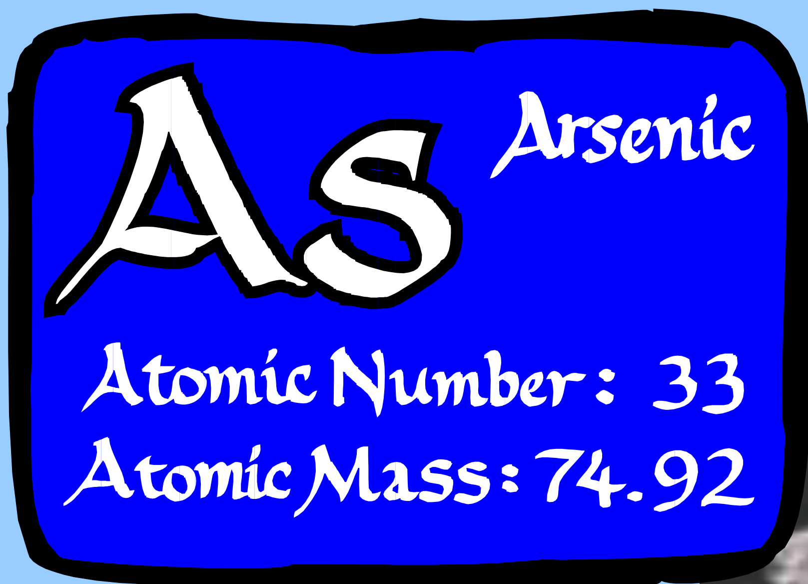
- Contaminant Candidate List (CCL)

http://www.epa.gov/safewater/

Contaminants of Concern

- Arsenic
- Nitrate
- Perchlorate
- Radionuclides

Arsenic



Arsenic - What is It?

- Naturally occurring element

- Natural sources
  - Erosion, dissolution, and weathering of rocks
  - Volcanoes
  - Forest fires

- Manmade/man-affected sources
  - Agriculture
  - Wood preservatives

Arsenic - Health Risks

- **Acute**
  - Stomach pain, nausea, vomiting, diarrhea
  - Numbness in hands and feet
  - Periorbital swelling

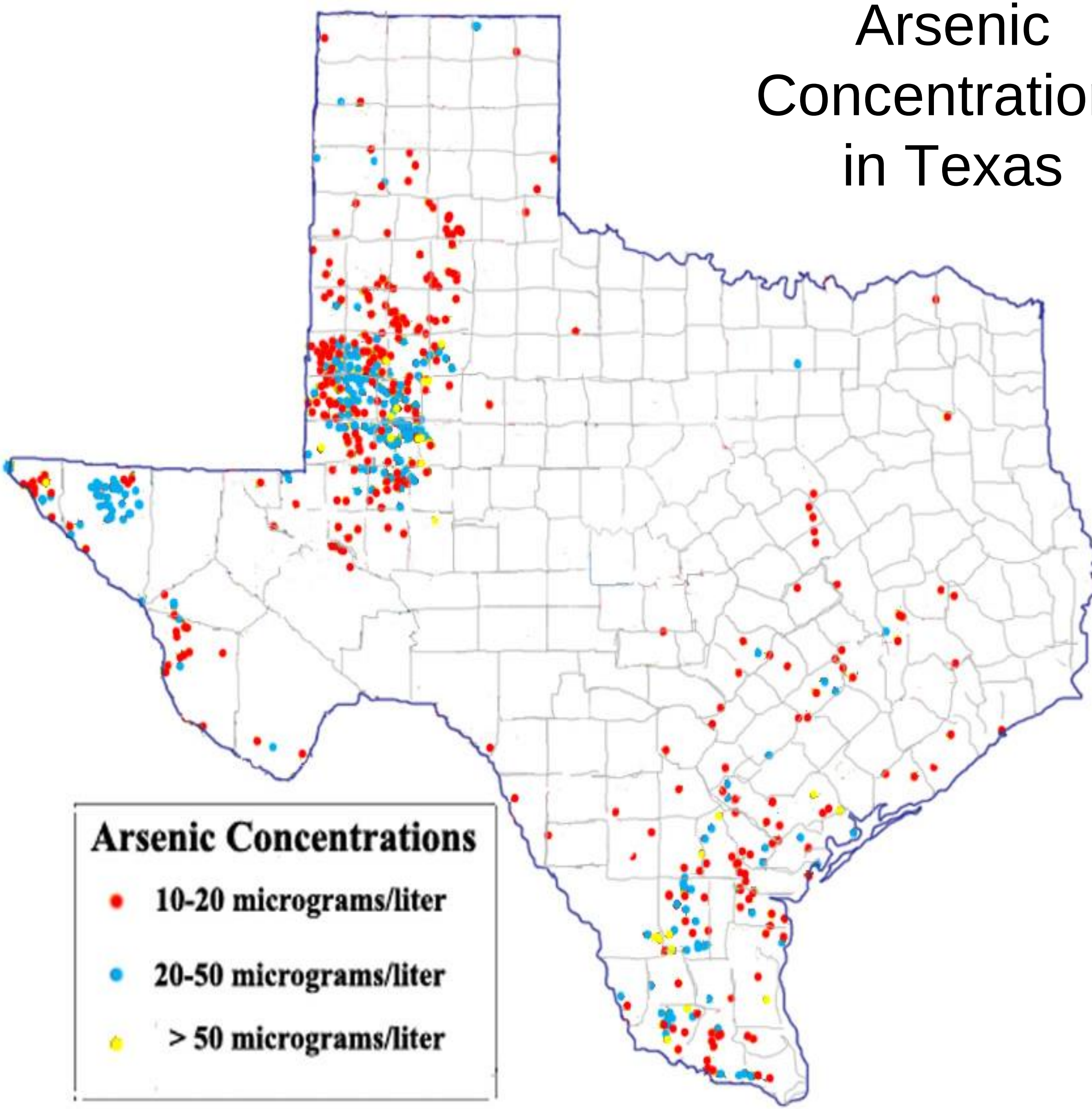
- **Chronic**
  - Dermal Effects
  - Hypertension
  - Cardiovascular Effects
  - Diabetes
  - Cancer

Arsenic - MCL

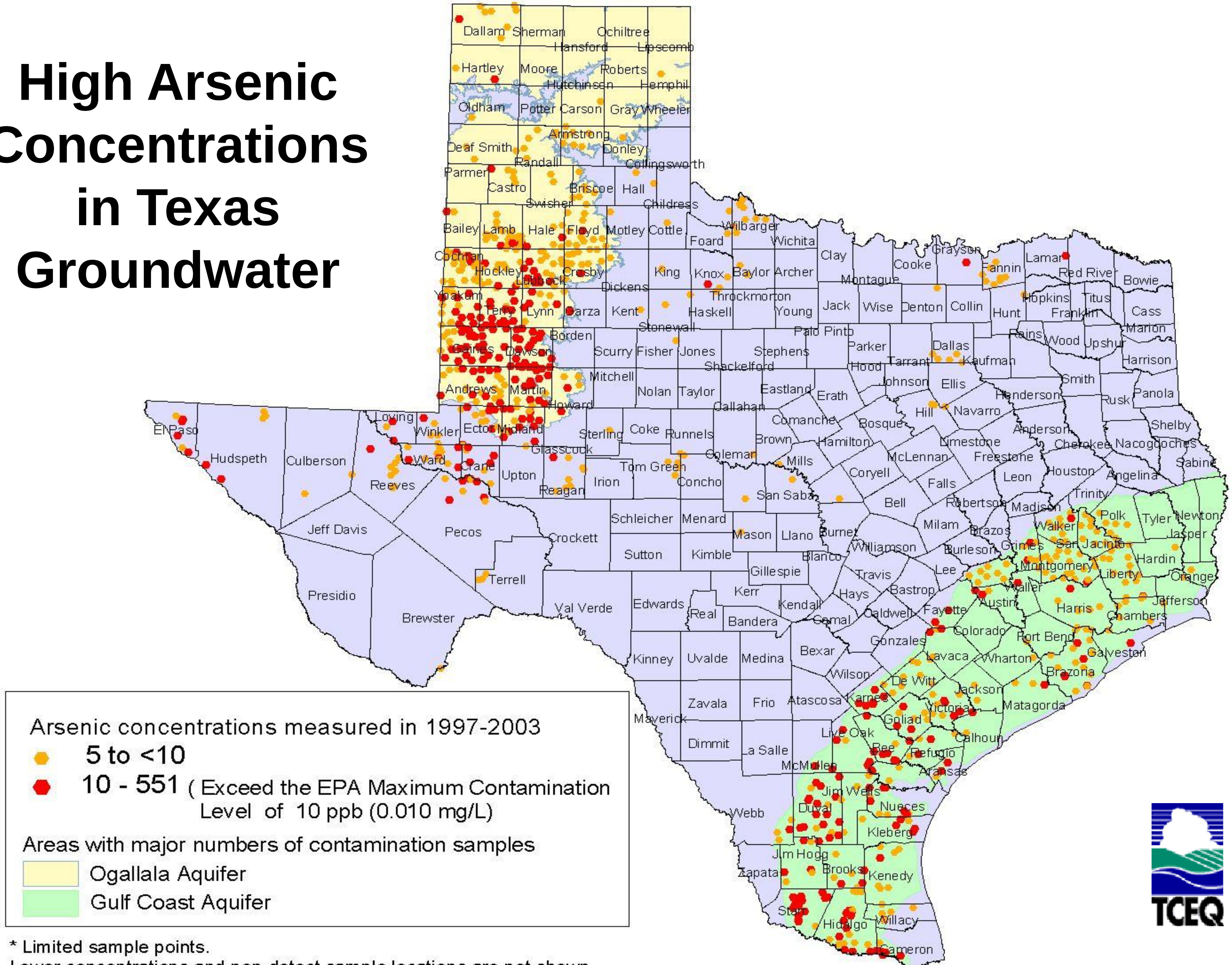
- The new Maximum Contaminant Level (MCL) for arsenic is 10 ppb.

- The EPA estimates that 350,000 people in the U.S. drink water containing more than 50 ppb, and nearly 25 million people drink water containing more than 25 ppb.

Arsenic Concentrations in Texas



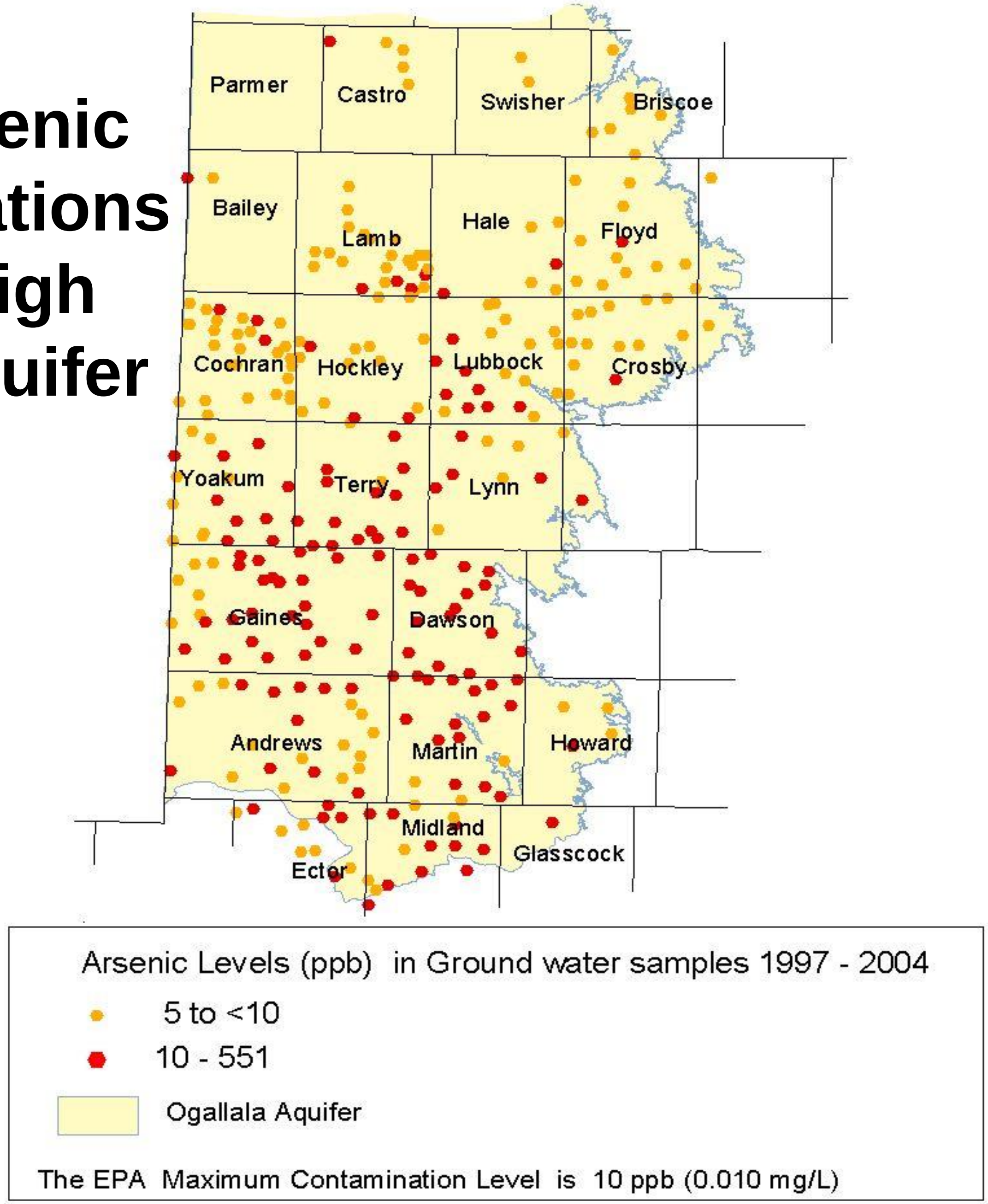
High Arsenic Concentrations in Texas Groundwater



* Limited sample points.

Lower concentrations and non-detect sample locations are not shown.

High Arsenic Concentrations in the High Plains Aquifer



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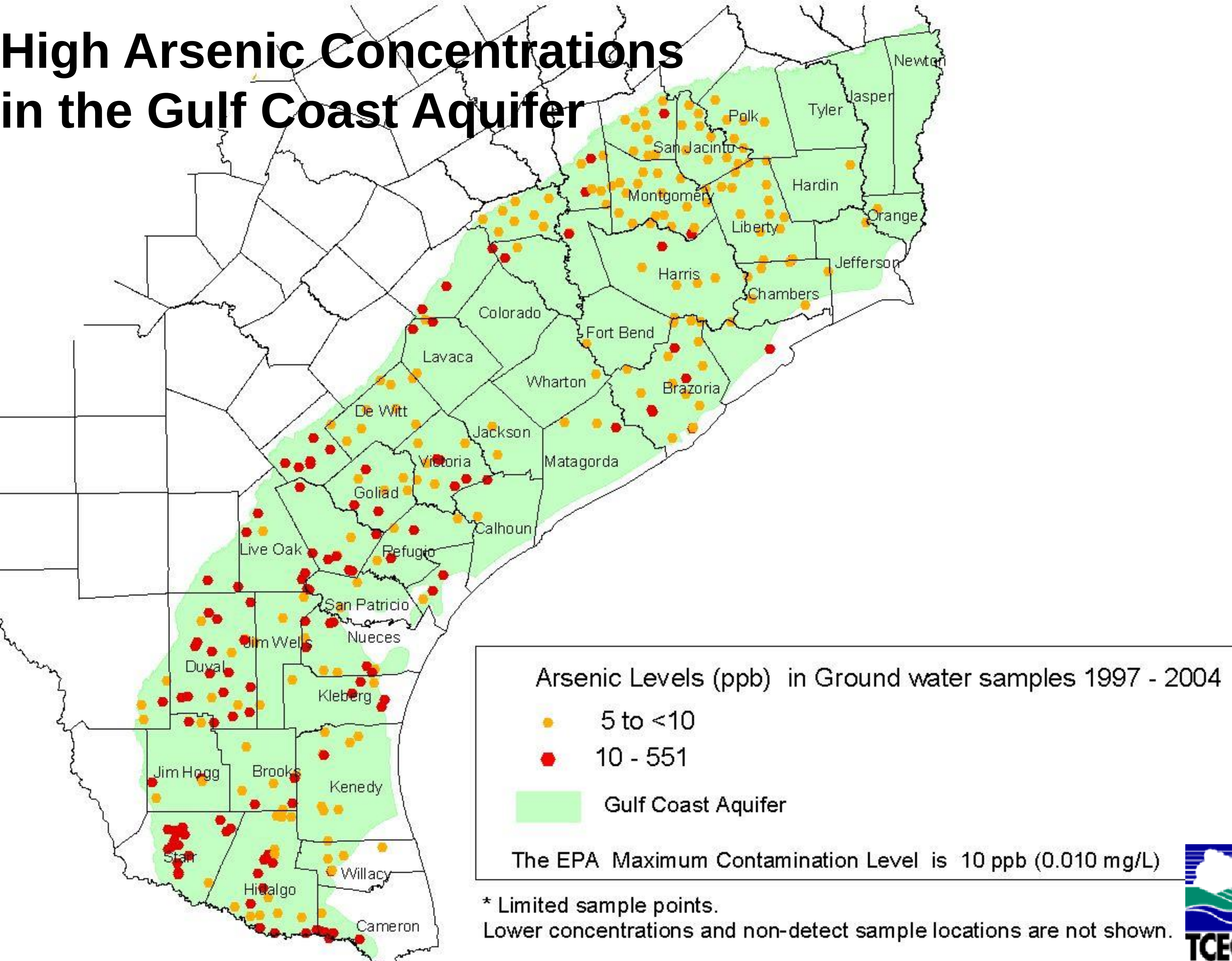
High Arsenic Concentrations in the Gulf Coast Aquifer



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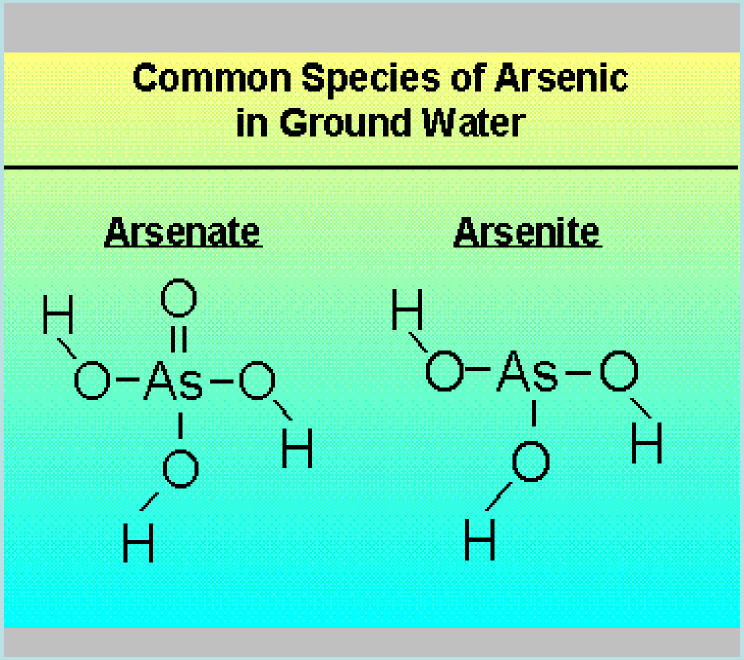
TCEQ

Arsenic - Treatment

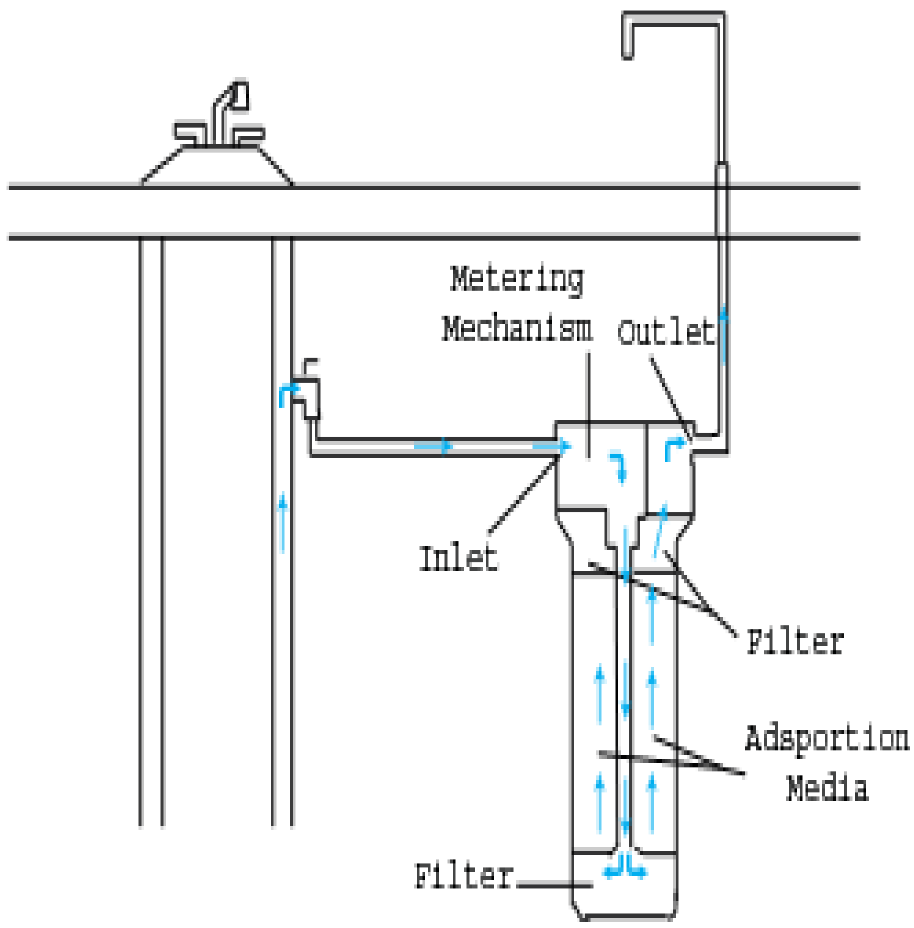
- Treatment is dependent on oxidation state
  - Arsenate - As(V)
    - Effective removal
  - Arsenite – As(III)
    - Must undergo oxidation to be effectively removed



Arsenic – Treatment Options

- ***Adsorption***
- ***Reverse Osmosis (RO)***
- ***Distillation***
- ***Ion Exchange (IE)***

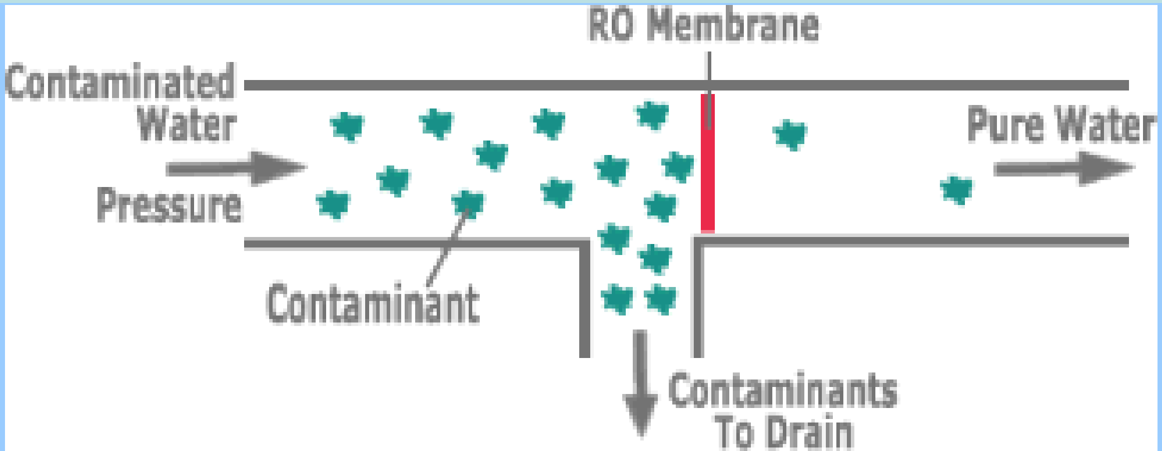
Arsenic - Adsorption



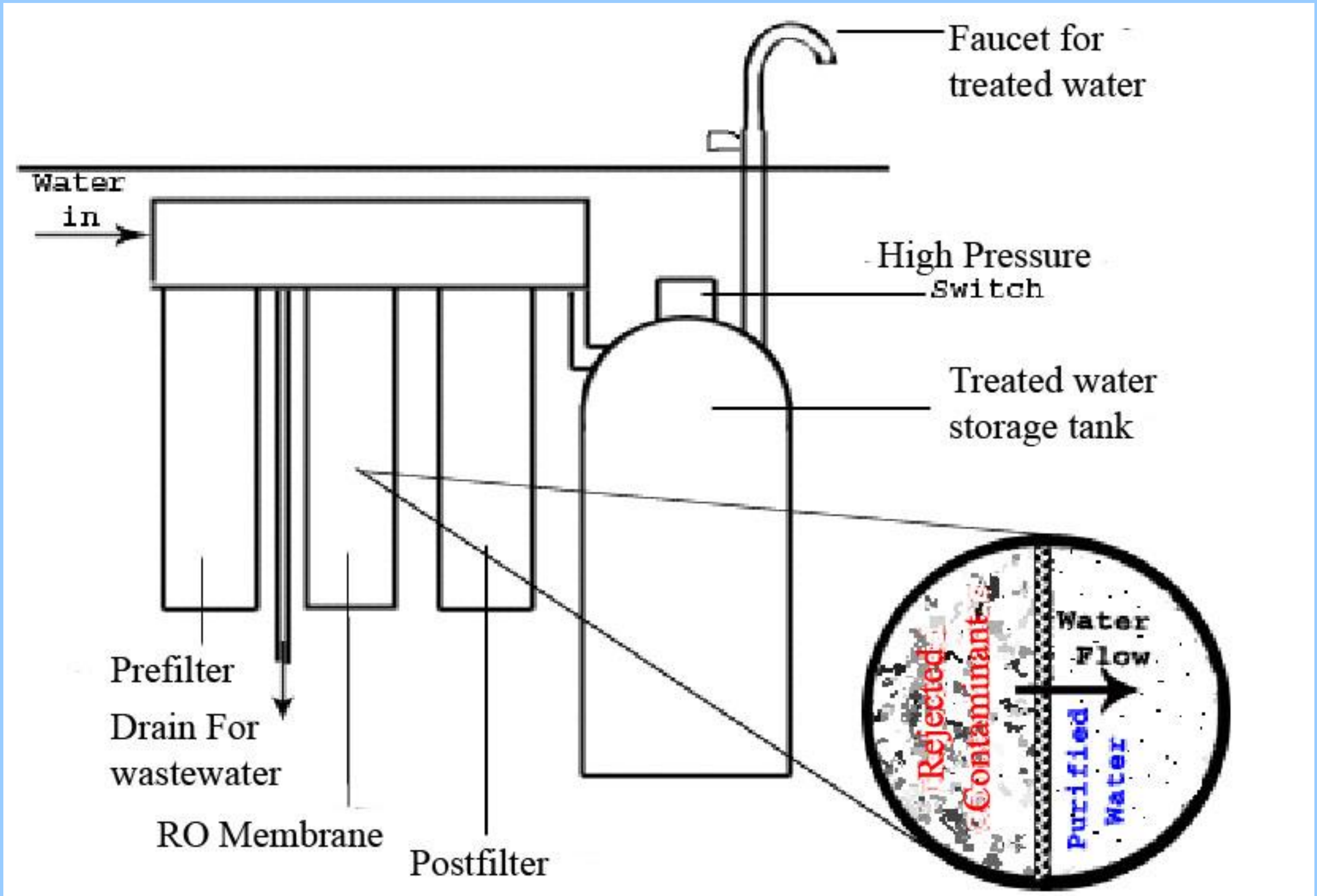
- Activated alumina and iron-based sorbents
- Advantages
  - Simple operation
  - Low maintenance
  - Low relative cost
  - Small under-the-counter footprint
  - Slow breakthrough kinetics

Arsenic - Reverse Osmosis

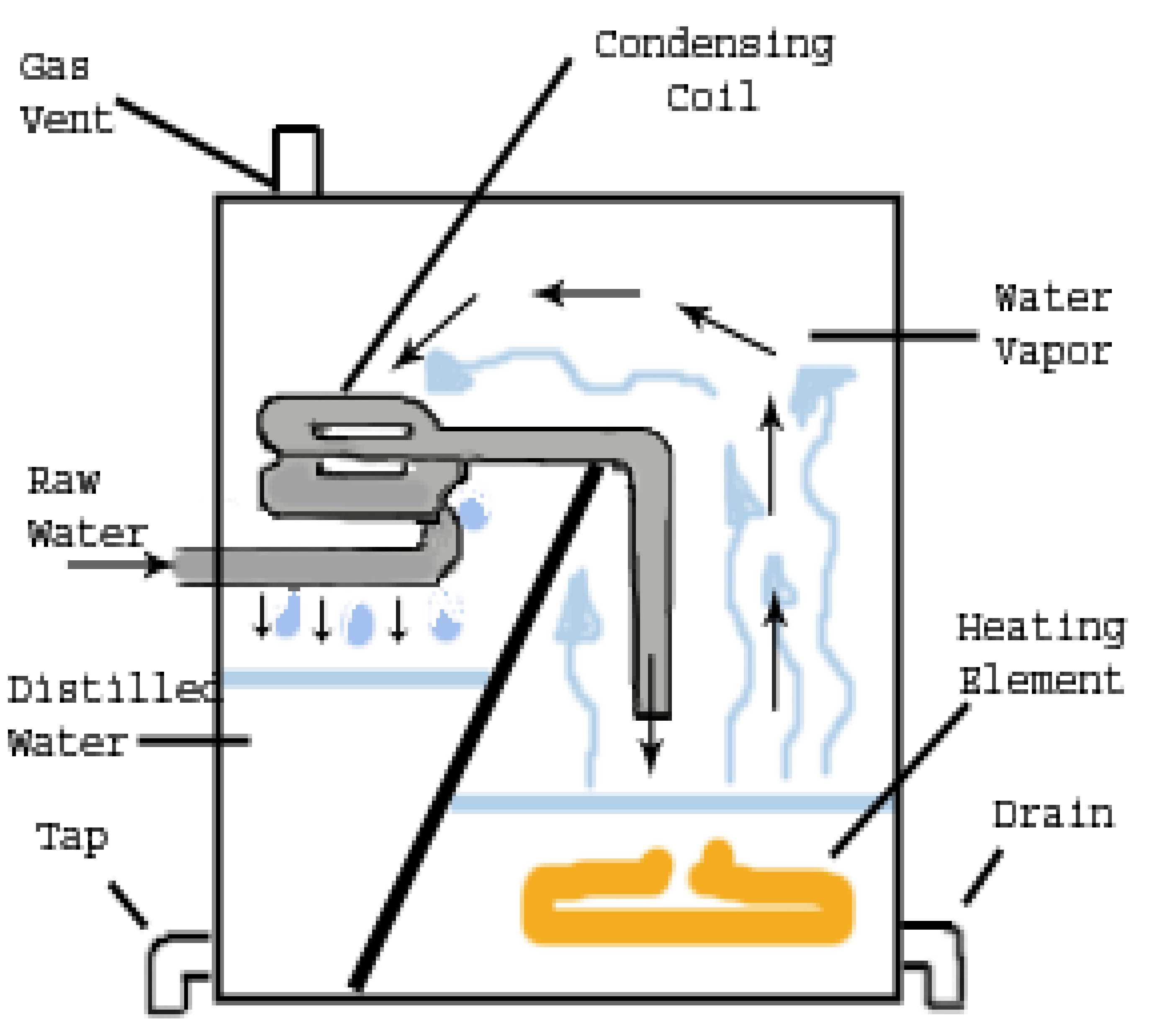
- Advantage
  - Achieves greater than 95% removal
- Disadvantage
  - Relatively poor water recovery
    - Most units designed to achieve 20-30% recovery
    - Used to treat drinking and cooking water only



Arsenic - Reverse Osmosis



Arsenic - Distillation



Arsenic - Distillation

- Majority of the cost is associated with energy requirement

$$Cost / gal = 0.024 \times \frac{\text{Wattage of unit}}{\text{Production } (gal / day)} \times \text{cost of electricity } (\$/\text{kWh})$$

Example

$$0.024 \times \frac{1100}{15 \quad gal / day} \times \$0.07/\text{kWh} \approx \$0.13 / gal$$

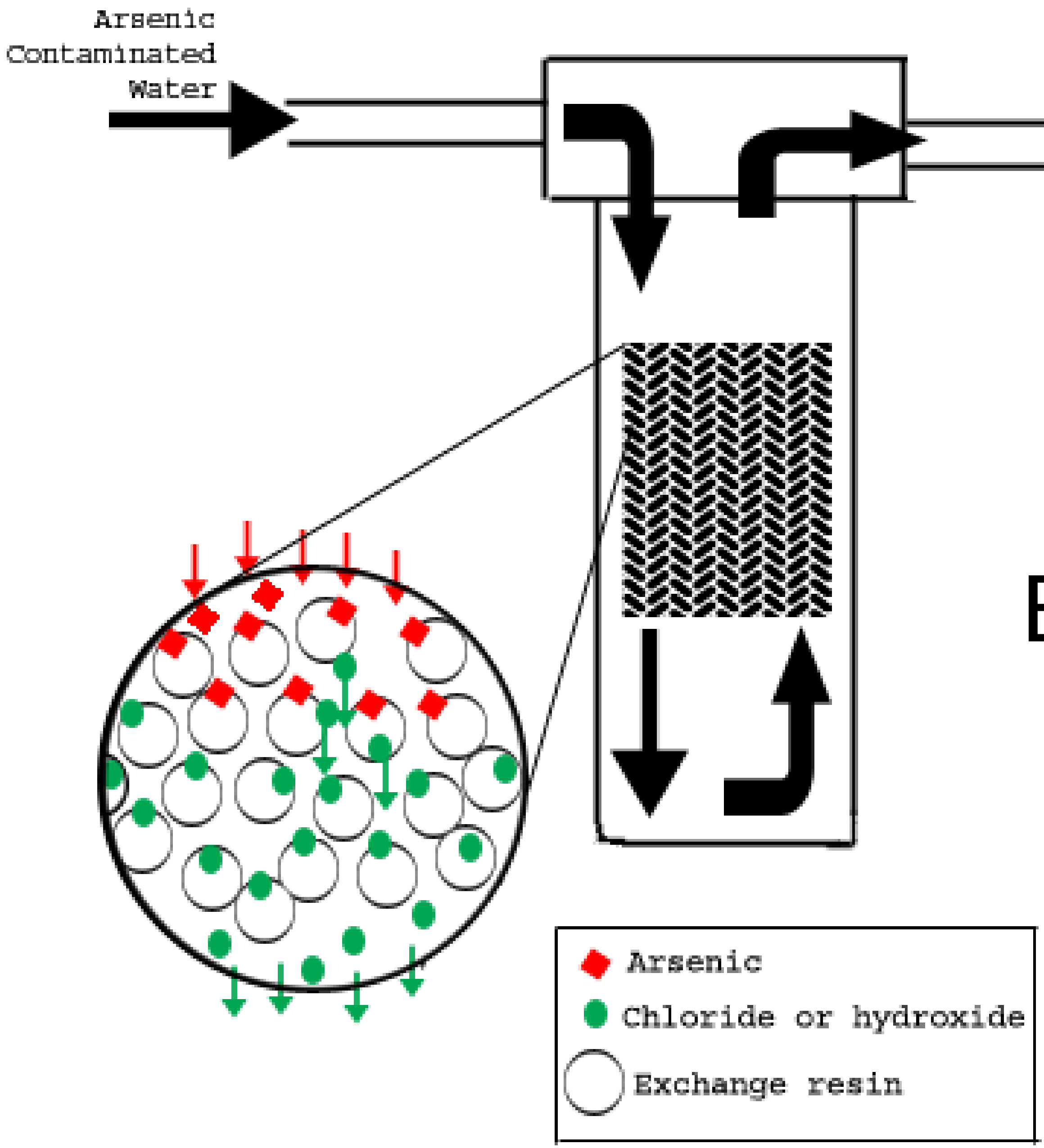
- Distillation units can be purchased for $300-$1200

Arsenic - Ion Exchange

- Removal based on the principle of charged particles (ions)
  - A positively charged particle is called a CATION.
  - A negatively charged particle is called an ANION.

- Cations and anions are attracted to each other.

Ion Exchange



Arsenic - Ion Exchange

- Not a good option if source water contains
  - > 500 mg/L of TDS,
  - > 50 mg/L SO_4^{-2} (sulfate)
  - high levels of nitrate or iron
- Chromatographic peaking

Nitrate

$$NO_3^-$$

Nitrate- What is It?

- Occurs naturally in both surface and groundwater
- Groundwater concentrations are elevated by
  - Natural occurrence
  - Overuse of fertilizers
  - Improper disposal of human and animal waste
- Very soluble in water

Nitrate – Health Risks

- In the United States, the average dietary intake of nitrate is about 75 to 100 mg per day.
  - 5 to 10% comes from drinking water

- In the body **nitrate** converts to **nitrite.**
  - Conversion process oxidizes the iron in hemoglobin
  - For children **6 months or younger** - results in a blue baby syndrome.

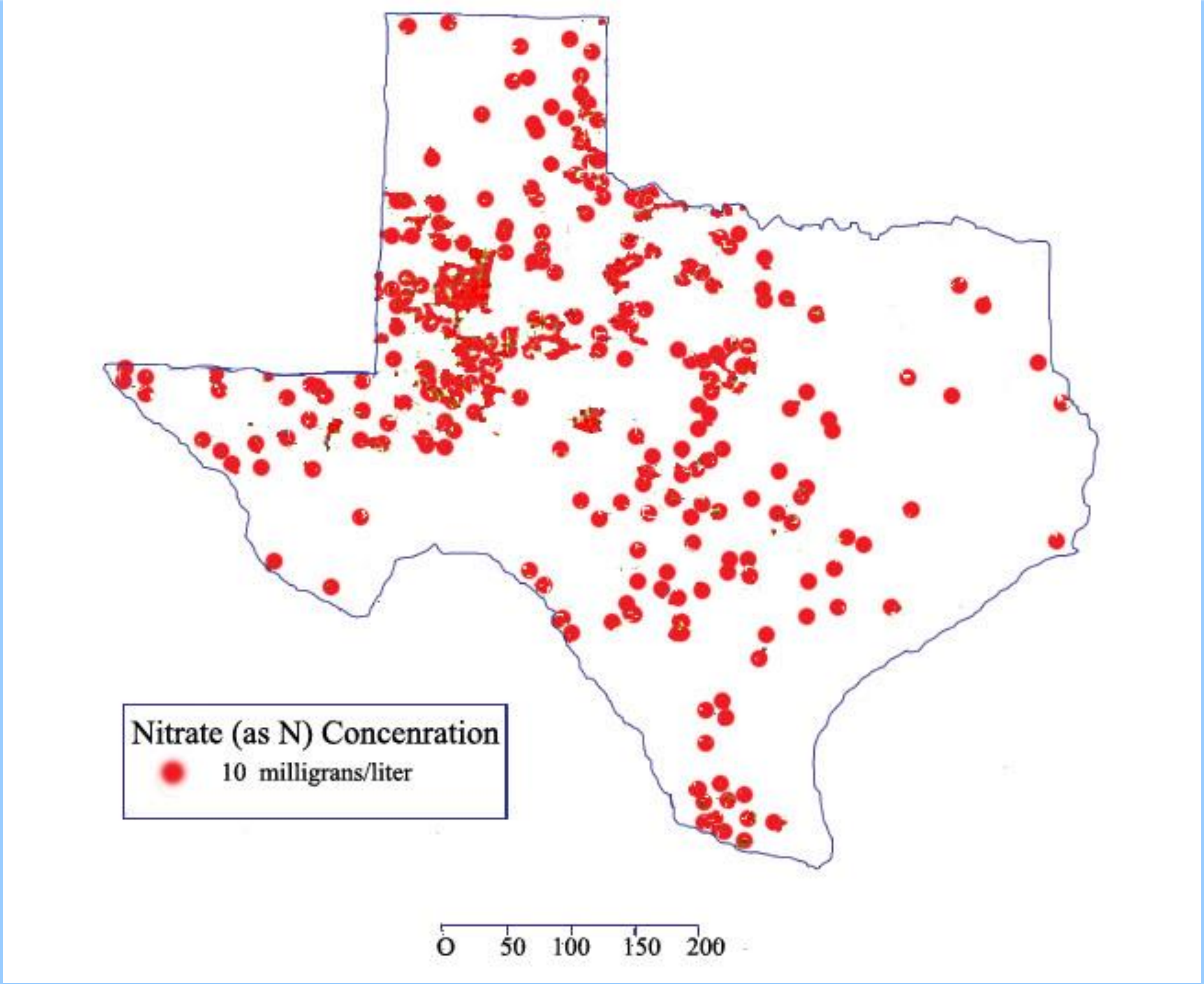
- Elevated nitrite intake may contribute to some cancers

Nitrate - MCL

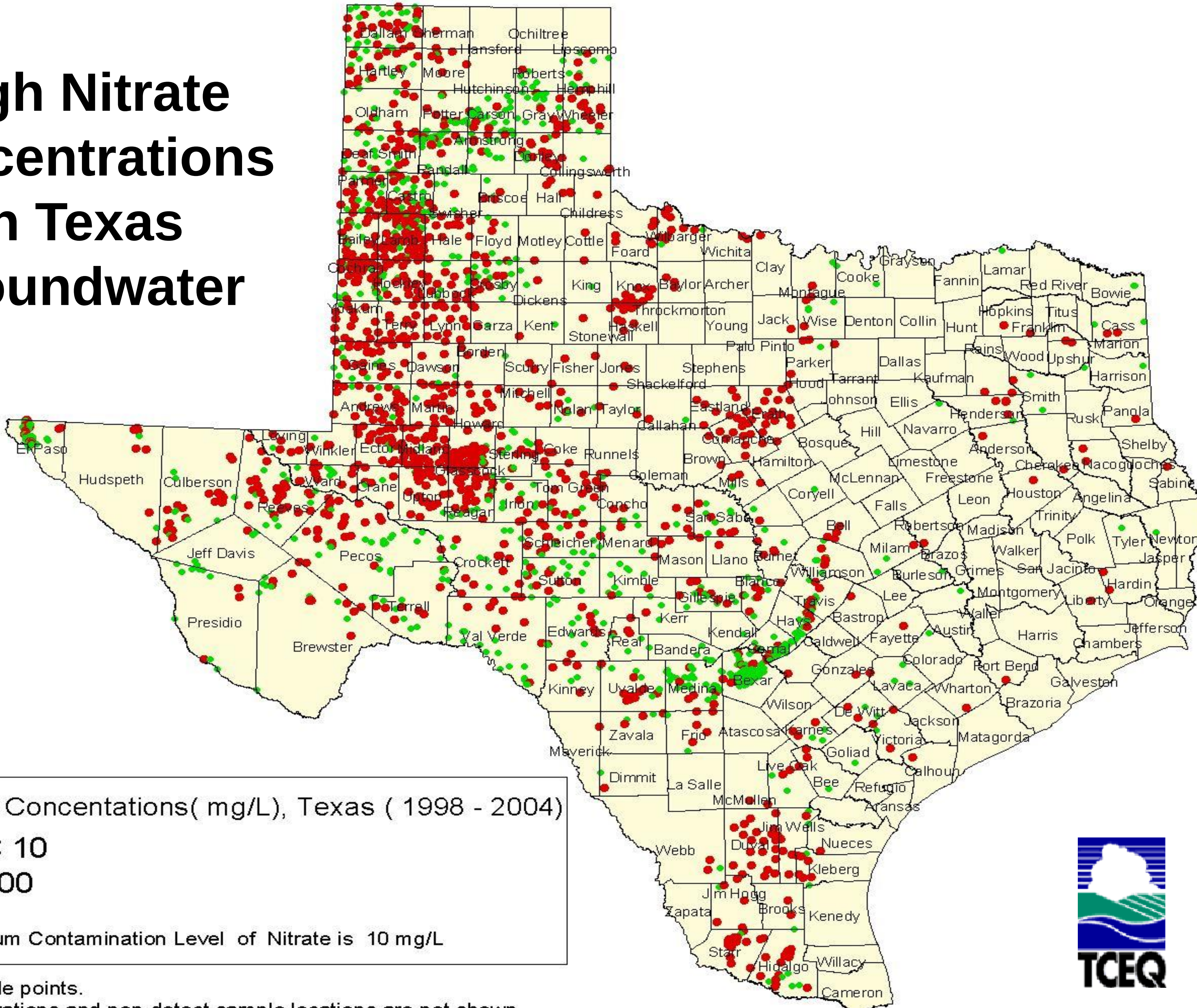
Drinking Water Standards (ppm):

	MCL
Nitrate:	10 as N
Nitrite:	1 as N

Nitrate Concentrations in Texas



High Nitrate Concentrations in Texas Groundwater



Nitrate-N Concentations(mg/L), Texas (1998 - 2004)

- 5 to < 10
- 10 - 500

EPA Maximum Contamination Level of Nitrate is 10 mg/L

* Limited sample points.
Lower concentrations and non-detect sample locations are not shown.

High Nitrate Concentrations in West Texas Groundwater

Nitrate Levels(mg/L) in Ground water samples 1998 -2004

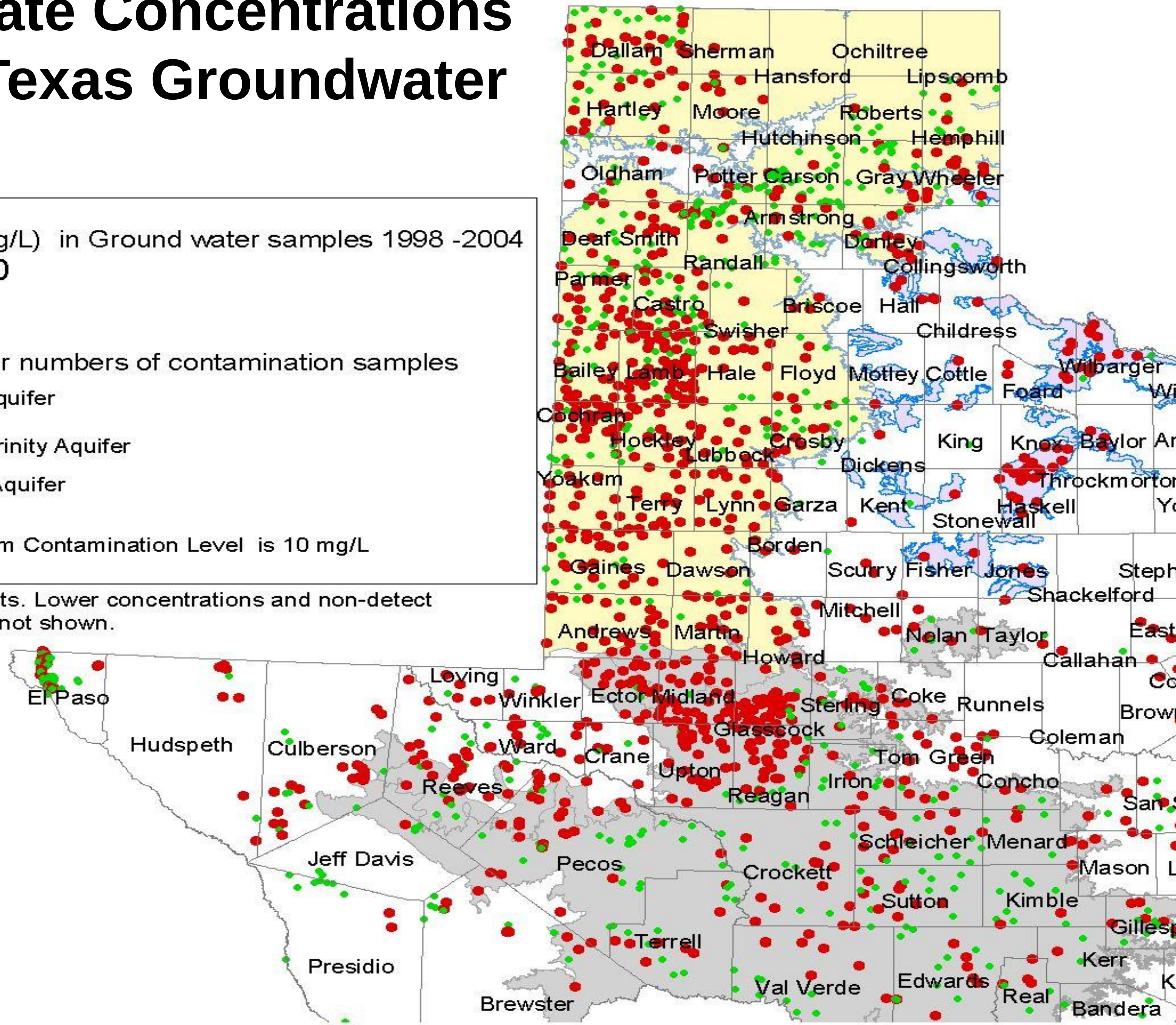
- 5 to < 10
- 10 - 500

Areas with major numbers of contamination samples

- Ogallala Aquifer
- Edwards Trinity Aquifer
- Seymour Aquifer

The EPA Maximum Contamination Level is 10 mg/L

* Limited sample points. Lower concentrations and non-detect sample locations are not shown.



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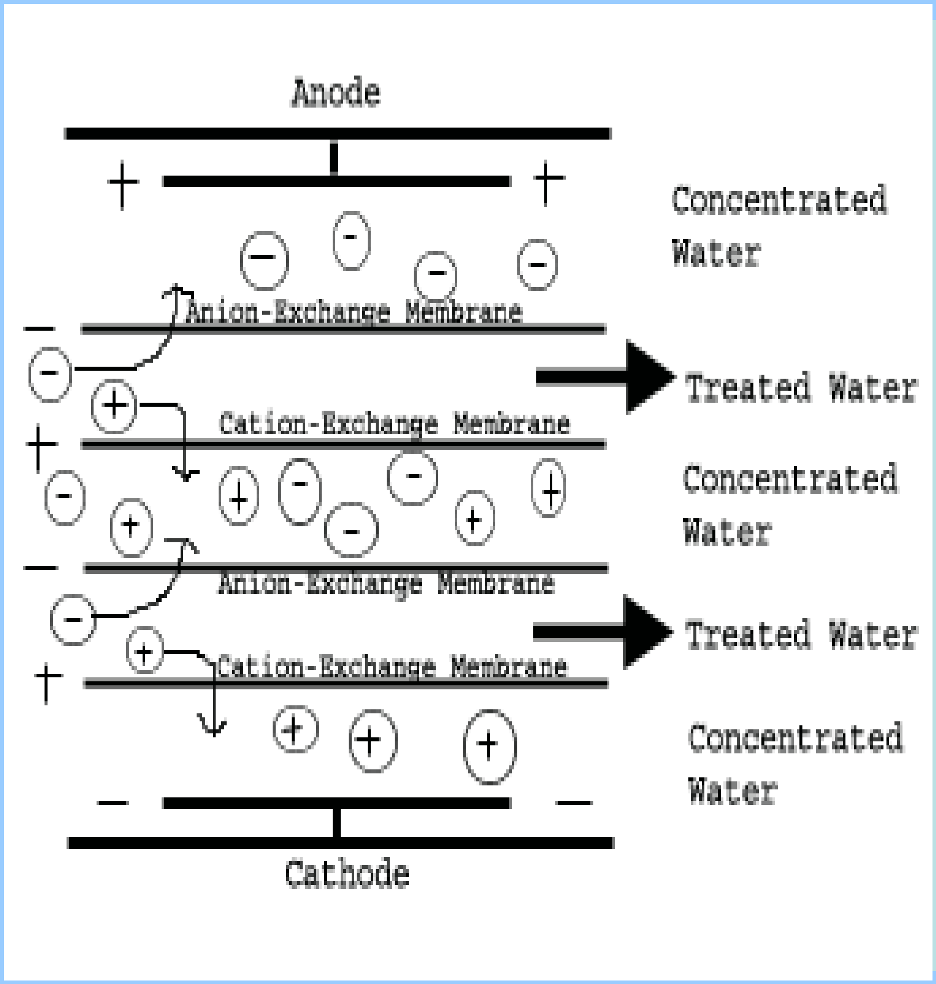
Nitrate – Treatment Options

- ***Reverse Osmosis (RO)***
- ***Distillation***
- ***Ion Exchange (IE)***
- ***Electrodialysis***

Electrodialysis



- Alternating anion- and cation-selective stacked membranes
- Nitrate drawn into the brine waste
- Disadvantages
  - Complicated
  - Costly
  - Potentially prohibited by local codes

Perchlorate

ClO_4

Perchlorate – What is It?

- Natural occurring and manmade chemical
- Very mobile in aqueous systems
- Sources of contamination
  - Fertilizer derived from Chilean caliche
  - Ingredient in solid propellant for rockets, missiles, and fireworks
  - Naturally occurring

Perchlorate – Health Risk

- Effect of low level chronic exposure is still not fully understood

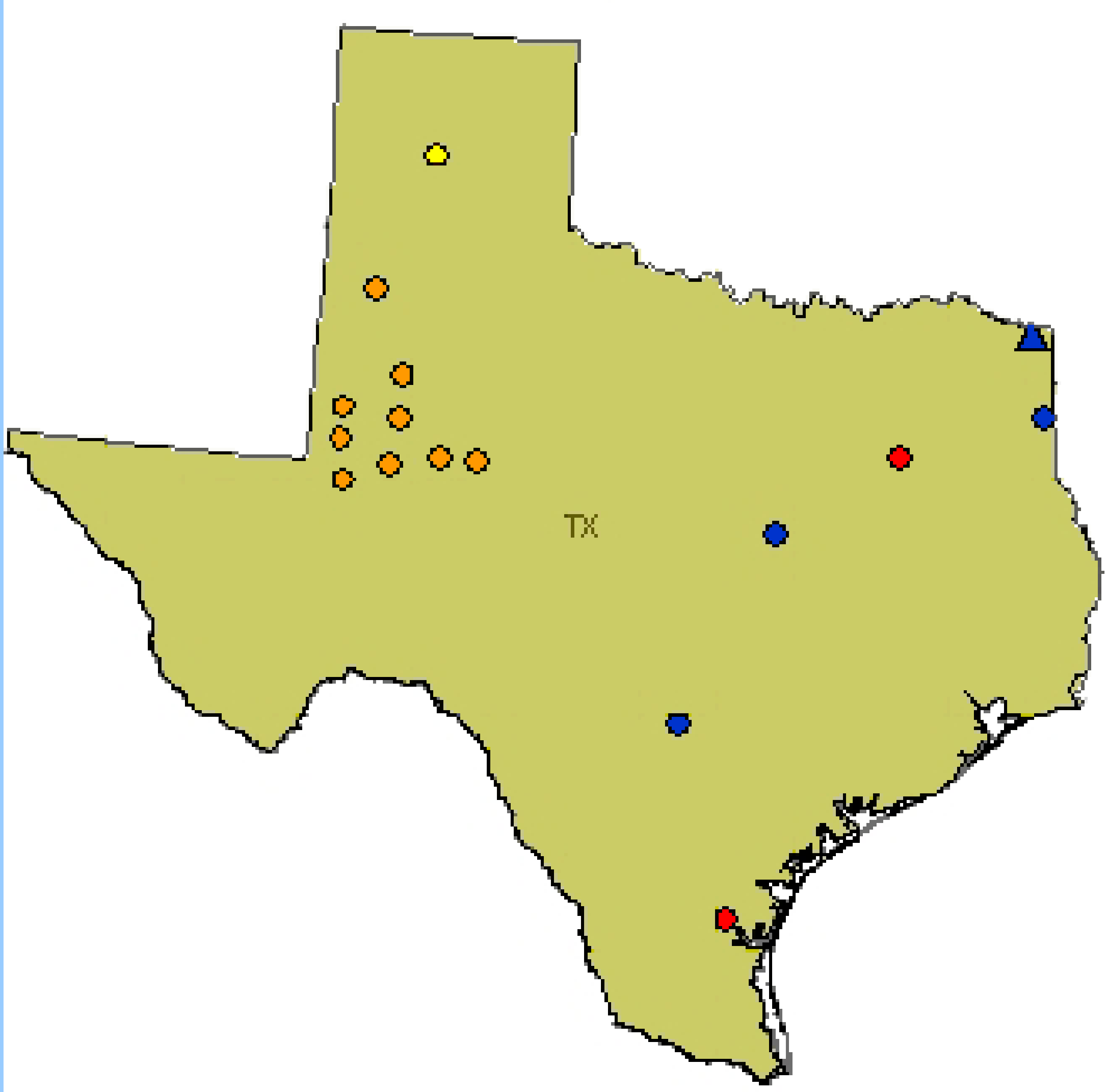
- Exposure to perchlorate is via the diet
  - Examples: Lettuce, milk, and drinking water

- Competitively blocks thyroid iodine uptake
  - Sensitive populations: fetuses, newborns, infants, young children, individuals with thyroid problems or iodide deficiencies.

Perchlorate – MCL

- No MCL
- EPA reference dose is .0007 mg/kg per day
- In Texas, current action level is 17 ppb
  - 4 ppb is used for public water systems.

Perchlorate Occurrence in TX



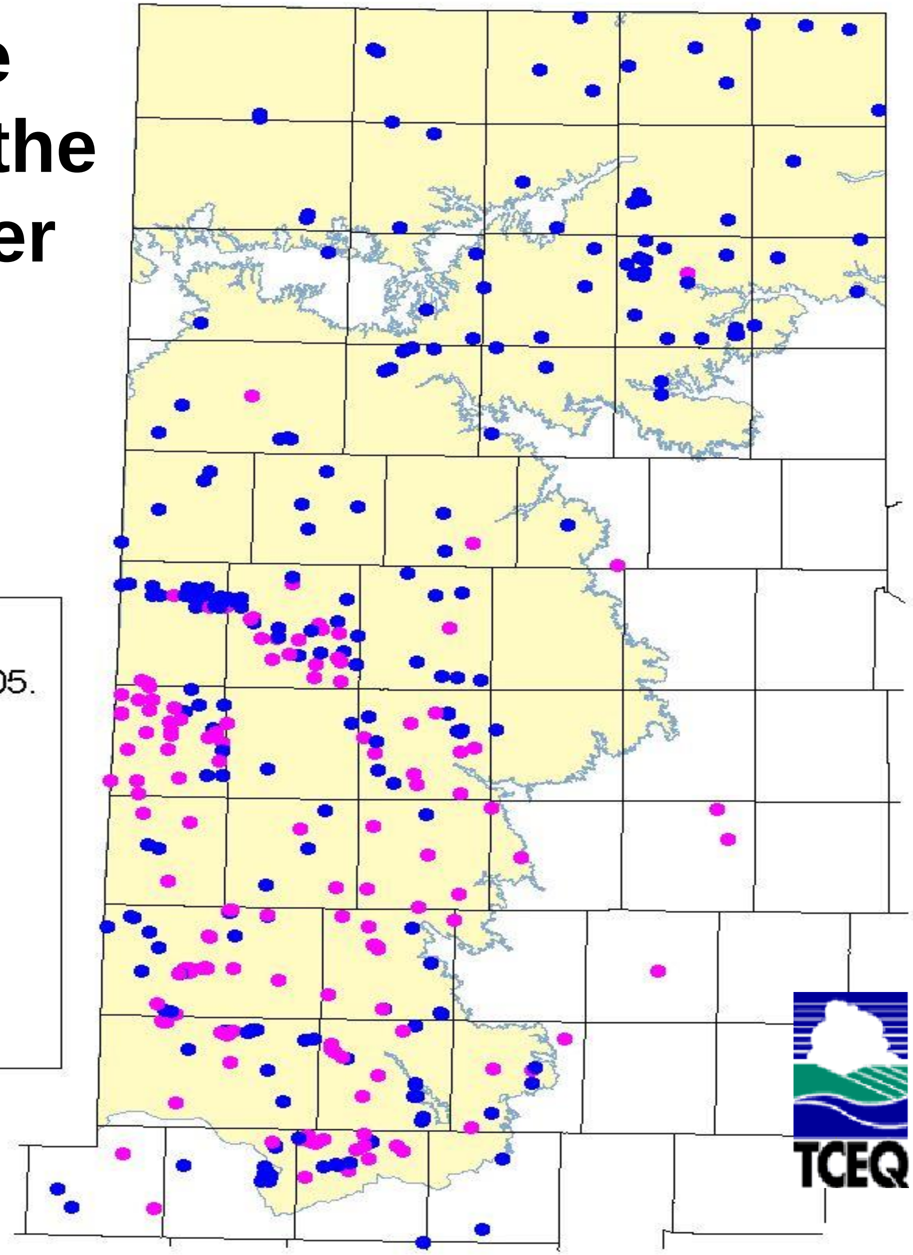
High Perchlorate Concentrations in the High Plains Aquifer

Perchorate Contamination, 2002 - 2005.

Perchlorate(mg/L)

- 0.1 to <4
- 4 - 58.8

Ogallala Aquifer



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Occurrence and Potential Sources of Perchlorate Releases to the Environment as of April 2003

Location	Suspected Source	Type of Contamination	Max. Concentration (ppb)
Andrews County	Unknown	Public Water Supply	15.8
Dawson County	Unknown	Public Water Supply Private Well	26 58.8
Ector County	Unknown	Public Water Supply	5
Gaines County	Unknown	Public Water Supply Private Well	27 30
Glasscock County	Unknown	Public Water Supply Private Well	1.1 3

Occurrence and Potential Sources of Perchlorate Releases to the Environment as of April 2003

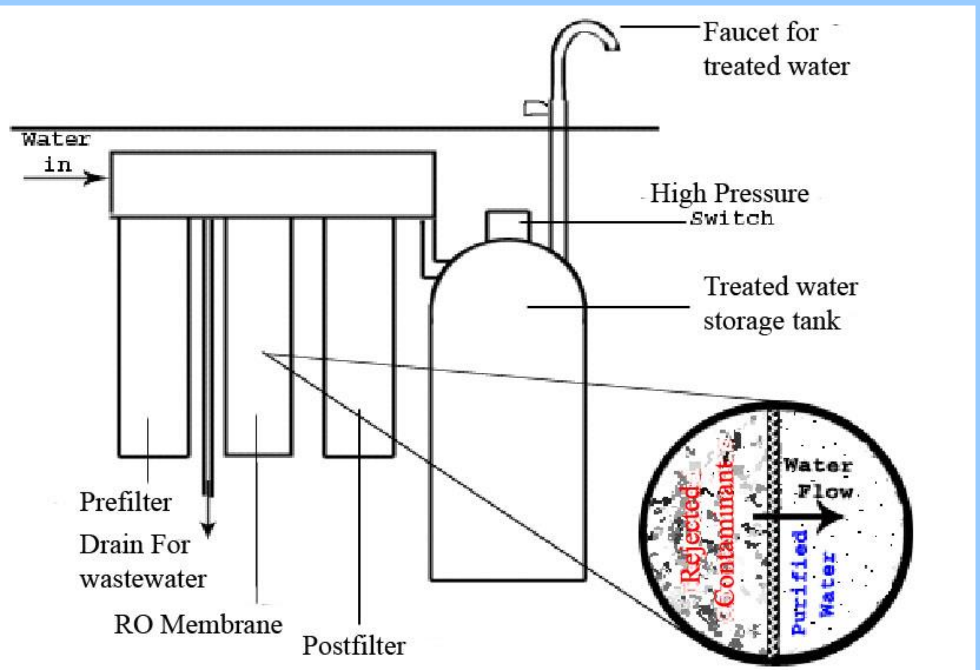
Location	Suspected Source	Type of Contamination	Max. Concentration (ppb)
Howard County	Unknown	Public Water Supply Private Well	1.4 26
Kleburg County	Unknown	Public Water Supply	4.5
Hockley County	Improper Cathodic Protection	Elevated Storage Tank	32
Lone Star Army Ammunition Plant, Texarkana	Propellant and Munitions Handling	Monitoring Well Surface Water	23 6
Longhorn Army Ammunition Depot, Kamak	Propellant Handling	Monitoring Well	169,000

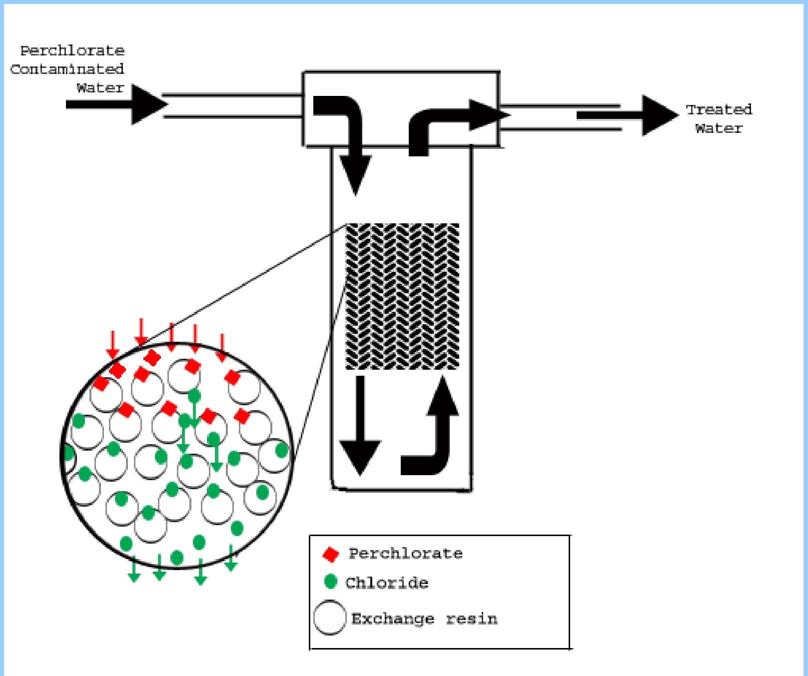
Occurrence and Potential Sources of Perchlorate Releases to the Environment as of April 2003

Location	Suspected Source	Type of Contamination	Max. Concentration (ppb)
Martin County	Unknown	Public Water Supply Private Well	32 19.1
McGregor Naval Weapons Plant	Propellant Handling	Monitoring Well	91,000
Midland County	Unknown	Public Water Supply	46
PANTEX Plant, Amarillo	Explosives	Monitoring Well	340
Red River Army Depot, Texarkana	Propellant Handling	Monitoring Well	80

Perchlorate – Treatment Options

- Reverse Osmosis
- Ion Exchange
  - Resin cannot be regenerated





Radionuclides

U Uranium
Atomic Number: 92
Atomic Mass: 238.03

Ra Radium
Atomic Number: 88
Atomic Mass: 226.03

Rn Radon
Atomic Number: 86
Atomic Mass: (222)

Radionuclides –What are They?

- Radioactive material
  - (Adjusted) Gross Alpha Emitters
    - Positively charged
    - Uranium and Radium-226 are examples
  - Beta particle emitters
    - Positively or negatively charged
    - Radium-228 and Tritium are examples
  - Radon
    - Gas

Radionuclides –How do They End Up in My Water?

- Mostly naturally occurring
  - From the Earth's crust (released as the rocks weather)
  - In the atmosphere (comes down with rain)
- Some manmade sources

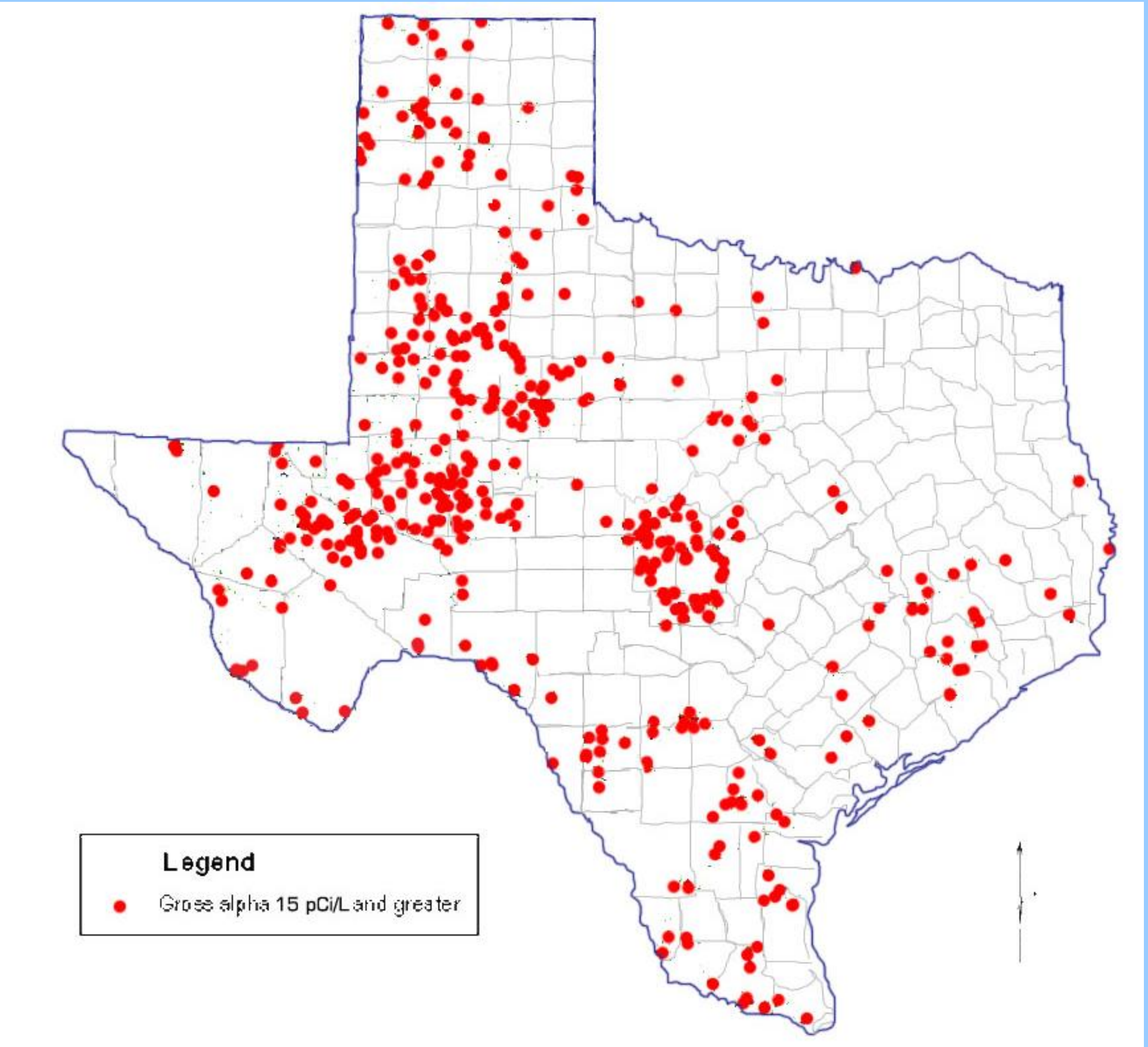
Radionuclides –Health Risks

- Radionuclides lead to an increased risk of cancer
- Uranium: kidney damage
- Radium
  - Bone growths
  - Osteoporosis
  - Tooth breakage
  - Kidney disease
  - Liver disease
  - Tissue necrosis
  - Cataracts
  - Anemia
  - Immunological suppression
  - Death
- Radon-lung and stomach cancer

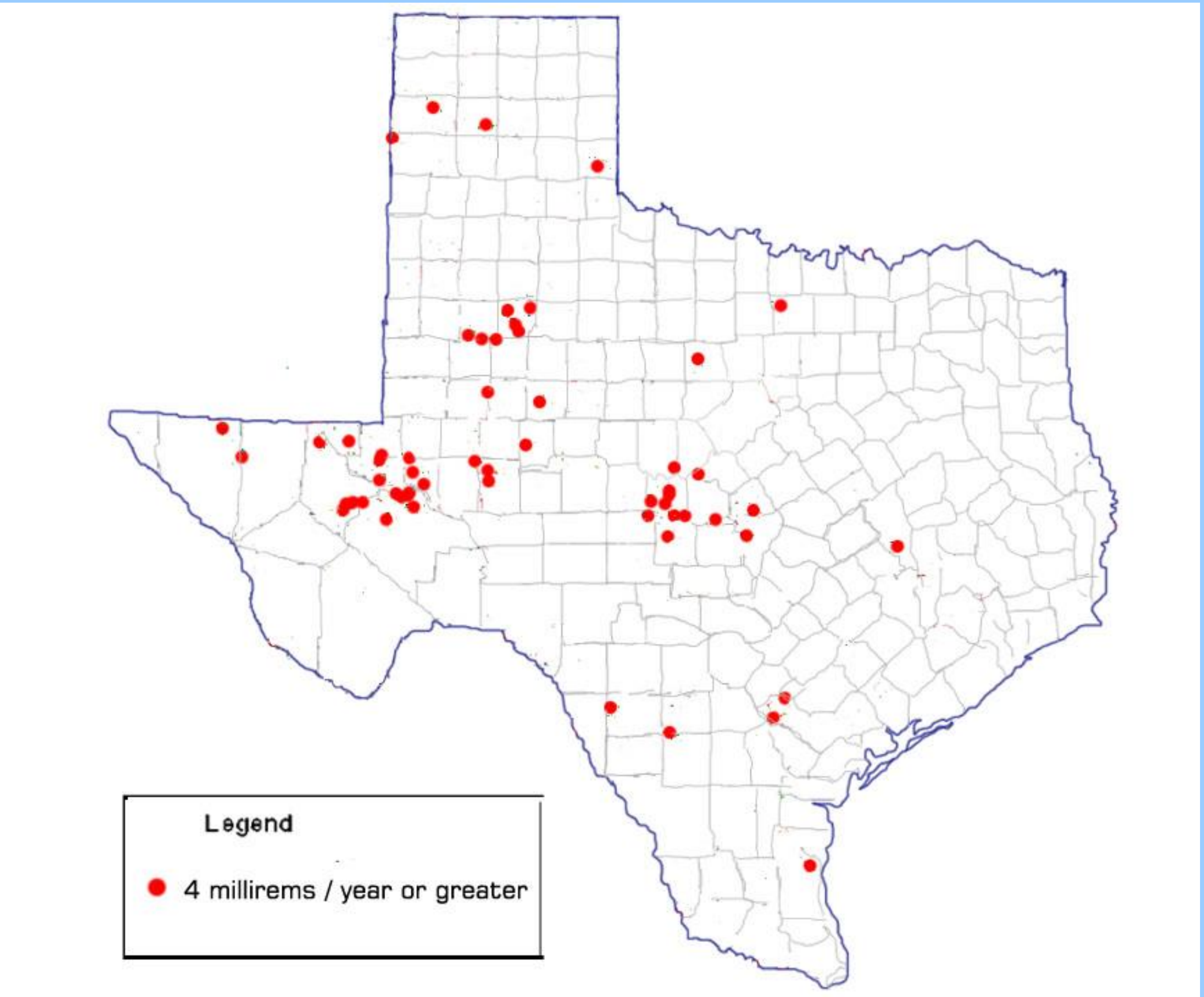
Radionuclides –MCL

- Beta- and Photon-Emitters: 4 millirems / year
- Alpha-Emitters: 15 pCi/L
- Uranium: 30 µg/L
- Radium: 5 pCi/L
- Radon: No current MCL (may become 4,000 pCi/L or 300 pCi/L depending on state's decision)

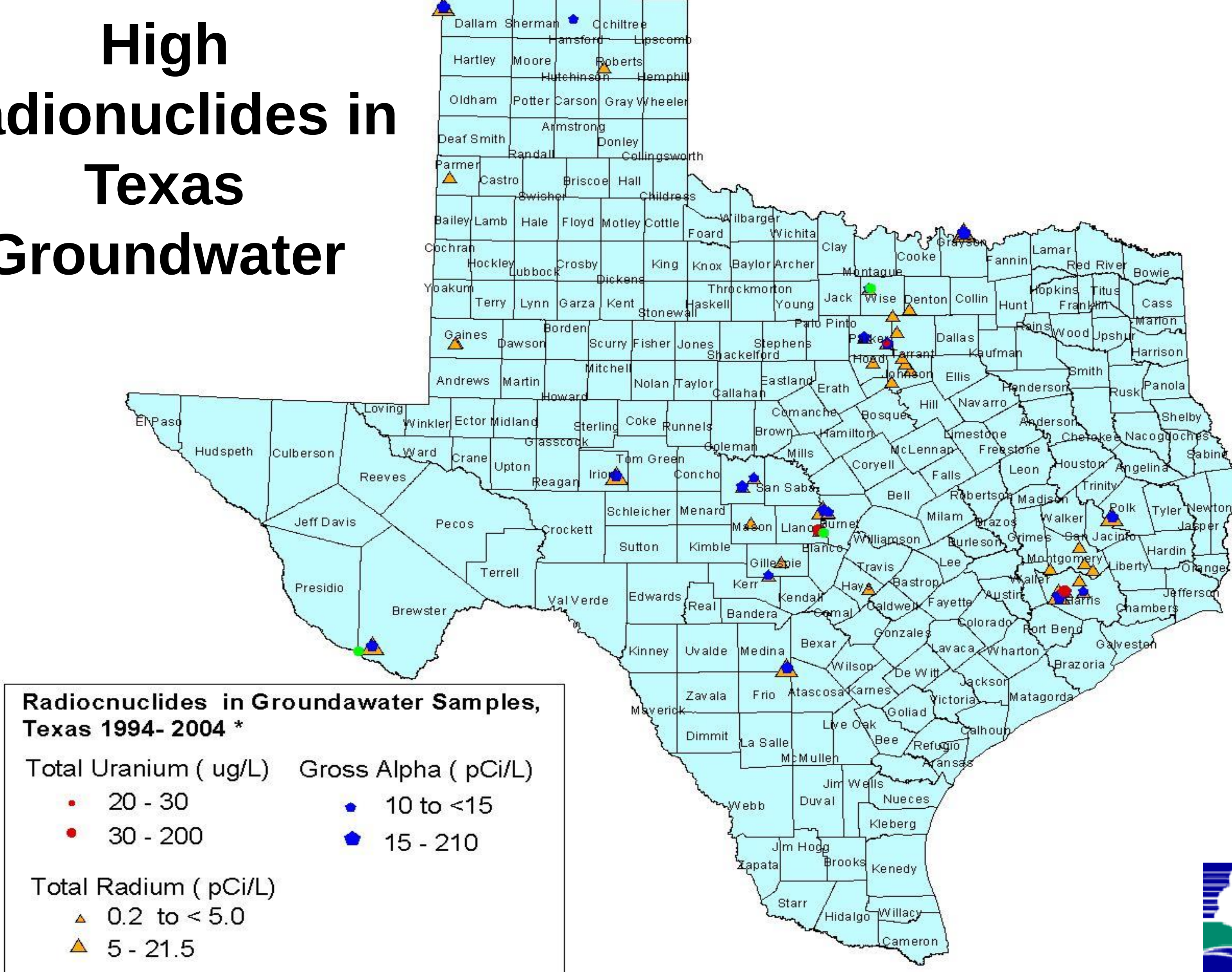
Gross Alpha Particle Activity in Texas Water Wells 1988-2004



Gross Beta Particle Activity in Texas Water Wells 1988-2004



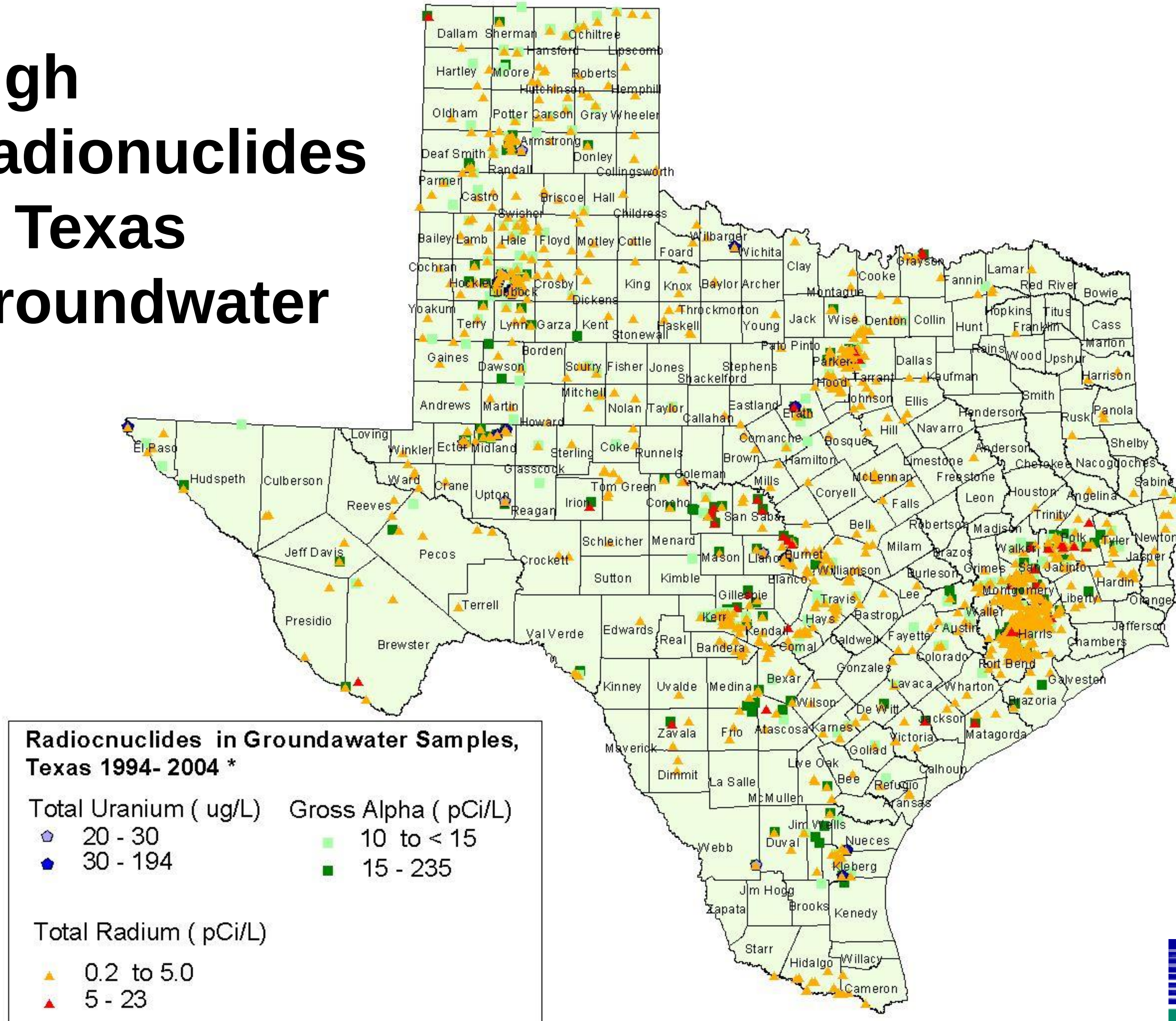
High Radionuclides in Texas Groundwater



Gross Alpha MCL = 15 picocuries per Liter (pCi/L)
Combined Radium MCL = 5 pCi/L
Uranium MCL = 30 ug/L

* Limited sample points.
Lower concentrations and non-detect sample locations are not shown.

High Radionuclides in Texas Groundwater



Gross Alpha MCL = 15 picocuries per Liter (pCi/L)
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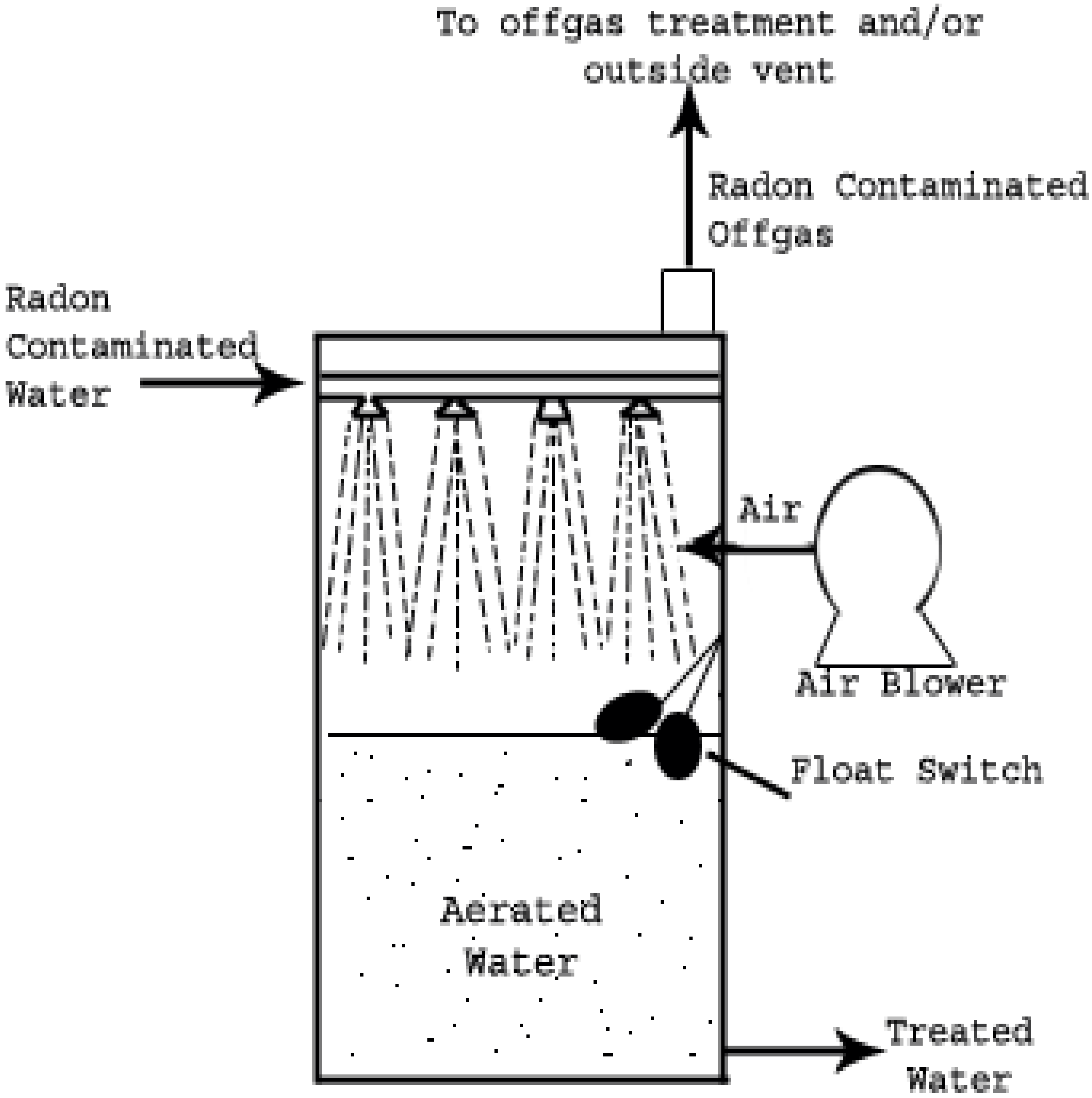
Radionuclides –Treatment Options

Contaminant	Treatment Technology
Radium (-226 and-228)	Ion Exchange (IE)- cation; Reverse Osmosis (RO); Distillation (D)
Radon-222	Aeration; Granular Activated Carbon (GAC)
Uranium	IE -anion; RO; D
Adjusted gross alpha emitters	RO; D
Gross beta and photon emitters	IE-mixed bed; RO; D

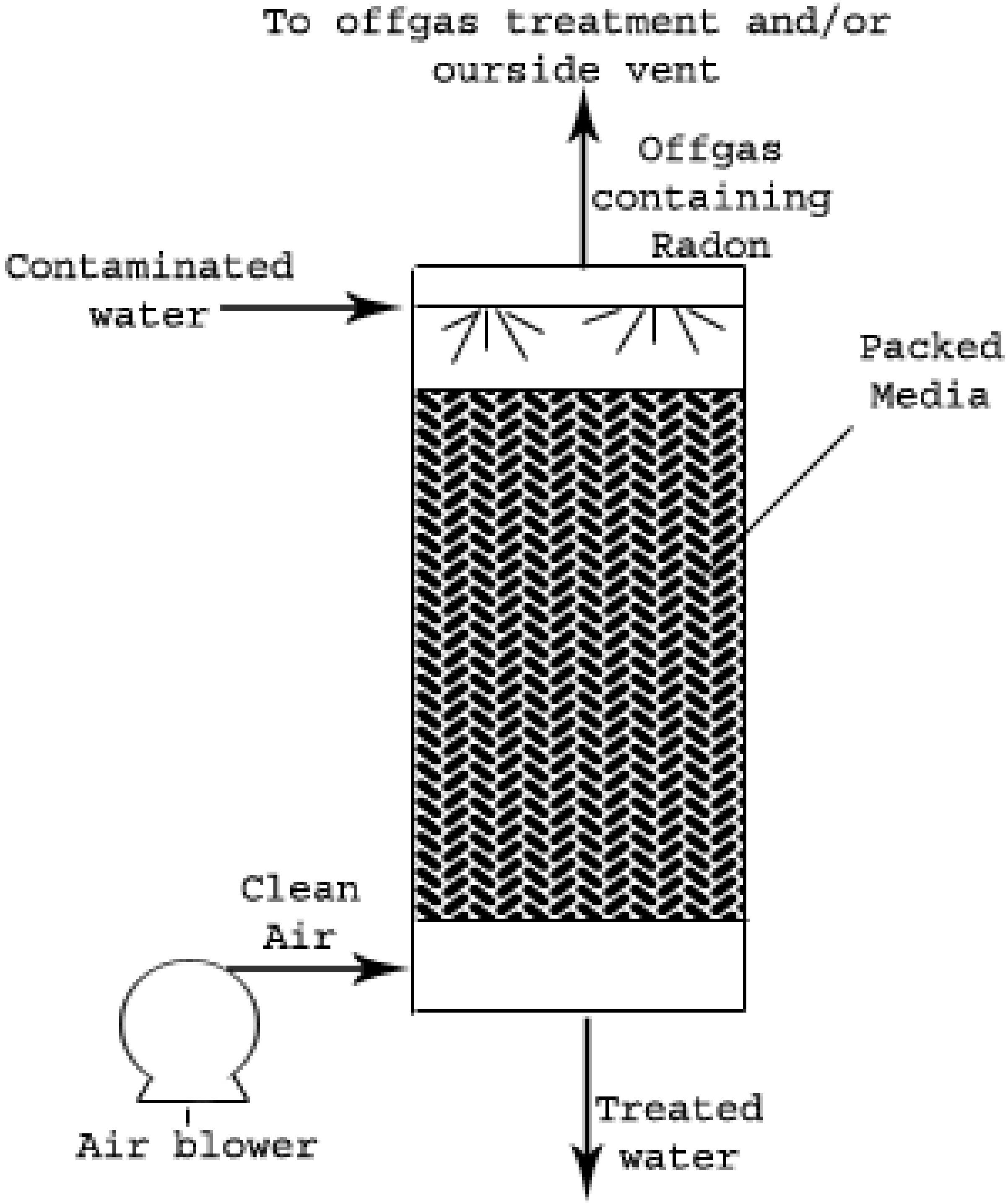
Radon Removal

- Granular activated carbon (GAC)
  - Do not use point-of-use systems

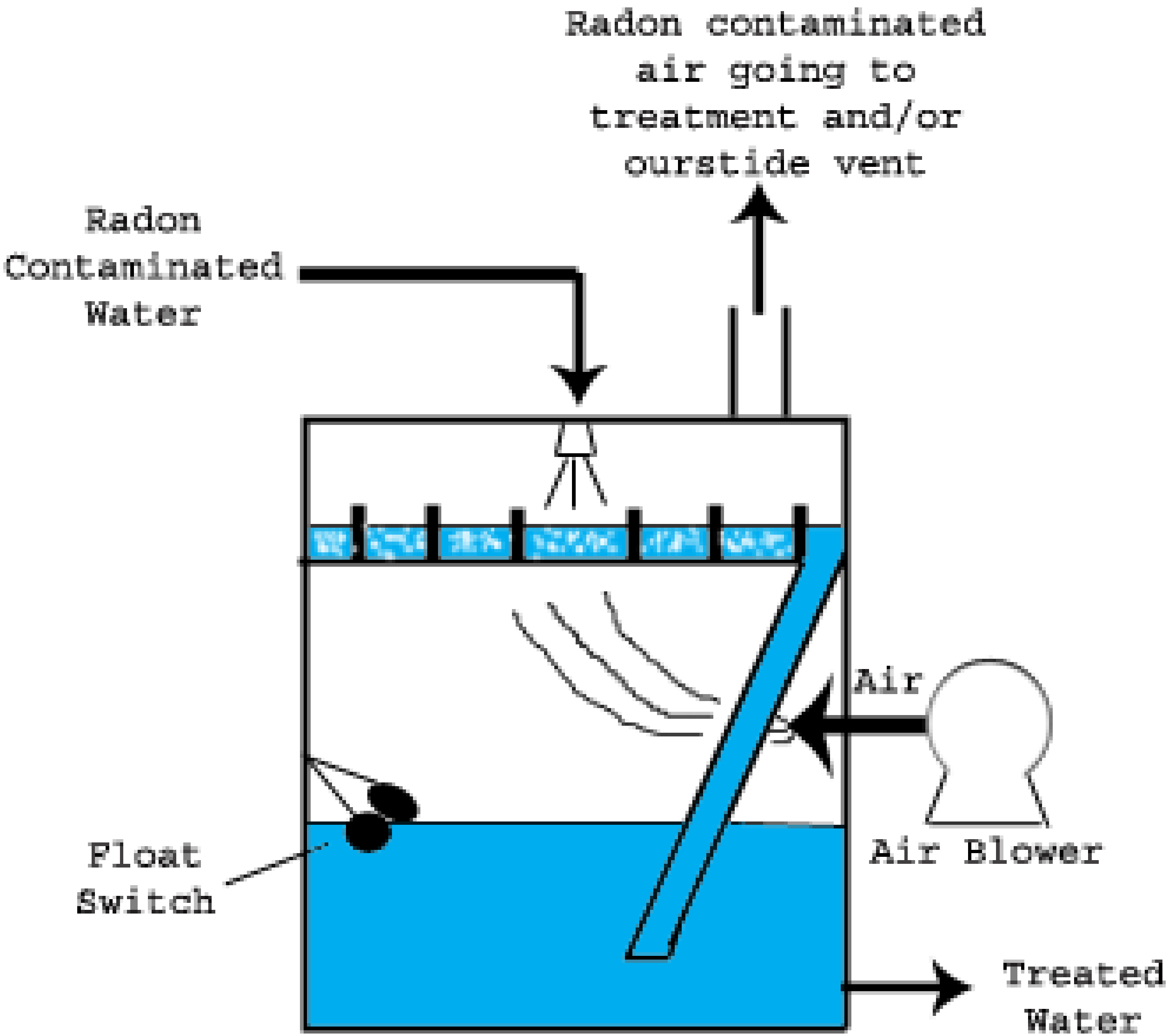
- Aeration
  - Preferred method of removal
  - Up to 99.9% removal
  - Three main types
    - Spray aeration
    - Packed column aeration
    - Shallow tray aeration



Spray Aeration



Packed Column Aeration



Shallow Tray Aeration

Which Treatment Option Should I Choose?

Treatment Options Summary

Technology	Contaminants*	Initial Cost±	Limitations
Ion Exchange	arsenic (As), perchlorate (P), nitrate (N), radium (R), uranium (U), gross beta emitters (β)	\$400-\$1500	competing contaminants
Reverse Osmosis	As, P, N, U, R, β, adjusted alpha emitters (α)	\$300-\$1000	poor water recovery
Distillation	As, N, R, U	\$300-\$1200	energy requirement

* Does not imply co-treatment capabilities for all contaminants listed.

± Only estimate of unit cost– does not include installation or O & M costs.

Treatment Options Summary

Technology	Contaminants	Initial Cost±	Limitations
Aeration	radon	$3000-	off-gas
Adsorption •AA & IBS •GAC	 As radon	 $100-$300 $300-$800	 microbial growth aeration is a better choice

± Only estimate of unit cost– does not include installation or O & M costs.

Selecting a Treatment Unit

- Qualified third-party lab water quality testing

http://www.tnrcc.state.tx.us/permitting/waterperm/pdw/chemlabs.pdf

- Find a system that will treat the constituents in the water

- Consider co-treatment compatibility if more than one constituent is present

Selecting a Treatment Unit

- Compare
  - Initial cost
  - O&M costs
  - O&M requirements
  - Contaminant removal efficiency
  - Warranties
  - Life expectancy
  - Company reputation
- Will you have a means of waste disposal?

Product Certification

- Water Quality Association (WQA)
  - Gold Seal Product Validation from the WQA
  - **http://www.wqa.org**
- The National Sanitation Foundation (NSF)
  - http://www.nsf.org/Certified/DWTU/
- EPA registration

Need More Information?

- Environmental Protection Agency
  - www.epa.gov/safewater/
  - Safe Drinking Water Hotline (1-800-426-4791)
  - www.epa.gov/surf
  - "Drinking Water From Household Wells"
  - *"Home Water Treatment Units"*

- Contact your County Extension Office