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SLIDES: Overview of Ground-Water Quality and Related Management Issues

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GROUND WATER IN THE WEST

***Overview of Ground-Water Quality and Related
Management Issues***

**Mike Wireman
Regional Ground-Water Expert
US EPA Region VIII**

A resource at risk!!



- ✓ 50 % of US population drinks GW
- ✓ Nearly all of rural population
- ✓ 50 bgd for agriculture

Discussion Topics

- **Natural Ground-Water Quality**
- **Ground-Water Contamination**
- **Ground-Water Management**

Ground Water in the West

Boulder, CO June 2004

Natural Ground-Water Quality

- **Nearly all GW originates as rain or snow that infiltrates to the saturated zone**
- **Infiltration through soil zone / vadose zone has great influence on chemistry of water**
- **Soil generates carbonic acid (H_2CO_3) and consumes dissolved oxygen**

Natural Ground-Water Quality

- **Chemistry of GW is controlled by rock-water interaction that occur as gw flows from areas of recharge to areas of discharge**
 - ✓ **Increases in total dissolved solids and major ions**
 - ✓ **Changes in dominant anions - $\text{HCO}_3 > \text{SO}_4 > \text{Cl}$**
 - ✓ **Cation concentrations vary due to reactions**

Dissolved Constituents in GW

➤ Major constituents

- (> 5mg/l)
- ✓ **Bicarbonate (HCO₃)**
- ✓ **Calcium (Ca)**
- ✓ **Chloride (Cl)**
- ✓ **Magnesium (Mg)**
- ✓ **Silicon (Si)**
- ✓ **Sodium (Na)**
- ✓ **Sulfate (SO₄)**
- ✓ **Carbonic Acid (H₂CO₃)**

➤ Minor constituents

- (> 0.01 -10mg/l)
- ✓ **Boron (B)**
- ✓ **Carbonate (CO₃)**
- ✓ **Fluoride (F_l)**
- ✓ **Iron (Fe)**
- ✓ **Nitrate (NO₃)**
- ✓ **Potassium (K)**
- ✓ **Strontium (Sr)**

Dissolved Constituents in GW

Trace constituents (< 0.1 mg/l)

- ✓ Aluminum
- ✓ Antimony
- ✓ Arsenic
- ✓ Barium
- ✓ Cadmium
- ✓ Chromium
- ✓ Copper
- ✓ Lead
- ✓ Manganese
- ✓ Lithium
- ✓ Phosphate
- ✓ Radium
- ✓ Selenium
- ✓ Silver
- ✓ Uranium
- ✓ Zinc

Dissolved Constituents in GW

Organics and gases

- **Organic constituents**
 - ✓ **Important species**
 - **H₂CO₃, CO₂, HCO₃, CO₃**
- **Ubiquitous**
- **Mostly fulvic & humic acid**
- ✓ **Atmospheric gases**
 - **N₂, O₂, CO₂**
- ✓ **Gases produced by anaerobic biochemical processes**
 - **CH₄, H₂S, N₂O**

TOTAL DISSOLVED SOLIDS

Classification for GW

- **Fresh water – 0-1000 mg/l**
- **Brackish water – 1000 –10,000 mg/l**
- **Saline water – 10,000 –100,000 mg/l**
- **Brine water - > 100,000 mg/l**

Hardness

- **The Content of Metallic Ions Which React With Sodium Soaps To or Scummy Residue**
 - **Soft - < 60 mg/l**
 - **Hard - 80 –100 mg/l**
 - **Very Hard - > 150 mg/l**
- **Water softening common when hardness > 80 mg/l**
- **Expressed as total concentration of Ca²⁺ & Mg²⁺ as mg/l equivalent CaCO₃**
- **GW in mountain watersheds underlain by granitic /metamorphic rocks is typically soft**

Isotopes in GW

- **Elements that have same # of protons in nucleus but different # of neutrons**
- **Same atomic # but different atomic weight**
- **Slightly different chemical properties**
- **Stable isotopes vs. radioisotopes**
- **Useful as tracers**

Isotopes Commonly Used in Hydrogeology

<u>Isotope</u>	<u>Symbol</u>	<u>Molecule</u>	<u>Type</u>	<u>Half-life</u>
Deuterium	D	H₂O	Stable	---
Oxygen- 18	¹⁸O	H₂O	Stable	---
Tritium	³H	H₂O	Radiogenic	12.7 years
Sulfur- 35 (1)	³⁵S	SO₄²⁻	Radiogenic	87 days
Carbon – 14	¹⁴C	CO₂	Radiogenic	5730 yrs

(1) – Still in proof of concept

Isotopic Ratios for Oxygen

Isotopic concentrations are expressed as the difference between the measured ratios of the sample and reference divided by the measured ratio of the reference. This is expressed using the delta (δ) notation:

$$\delta^{18}\text{O}_{\text{sample}} = \frac{m(^{18}\text{O}/^{16}\text{O})_{\text{sample}} - m(^{18}\text{O}/^{16}\text{O})_{\text{reference}}}{m(^{18}\text{O}/^{16}\text{O})_{\text{reference}}}$$

- ✓ $^{18}\text{O} / ^{16}\text{O}$ Ratio is changed by fractionation processes
- ✓ Snow –depleted in ^{18}O ; rain enriched in ^{18}O

Tritium (^3H) In The Environment

- **Produced by cosmic rays spallation of nitrogen**
Pre-bomb < 10TU in precip
- **Nuclear weapons testing - 1953 -1962**
Up to 1000 TU in precip in 1964
2000 - Tritium in precip approaching pre-bomb levels
- **GW mean residence times based on tritium**
 - < 0.8 TU - recharged prior to 1952
 - 5 -15 TU - modern - (<5 to 10Yrs)
 - > 30 TU - Considerable % of recharge from 1960's / 70's
 - > 50 TU - Dominantly 1960'2 recharge

Uses for isotopic data

- **Determine gw recharge areas**
- **Evaluate gw flowpaths**
- **Determine sources of TDS**
- **Relative age of gw – (length of time that gw has been out of contact with atmosphere)**

Natural Ground - Water Quality

- 1. Not well characterized**
- 2. Varies depending on which portion of aquifer (Recharge area vs. discharge area)**
- 3. Assessments typically based only on indicator parameters (TDS, SC)**
- 4. Aquifer monitoring efforts (baseline, ambient) have been greatly reduced in the last decade**

Ground-Water Contamination

- **Contaminants – All solutes introduced into the hydrologic environment as a result of human activities**
- **Pollution – when contaminant concentrations attain levels that are objectionable**

Types of GW Contaminants

1. **Synthetic organic chemicals (137 on EPA list)**
2. **Hydrocarbons**
3. **Inorganic cations (metals)**
4. **Inorganic anions**
5. **Pathogens**
6. **Radionuclides**

Types of GW Contaminants

- Synthetic organic chemicals (including hydrocarbons)
 - ✓ **Halogenated volatile organic compounds**
 - Solvents PCE, TCE, 1,2 DCE
 - ✓ **Non-halogenated volatile organic compounds**
 - Hydrocarbons (benzene, toluene)
 - ✓ **Halogenated semi -volatile organic compounds**
 - PCBs, Pentachlorophenol
 - ✓ **Non- halogenated semi-volatile organic compounds - phenols**

Types of GW Contaminants

➤ Toxic metals

- Arsenic
- Chromium
- Cadmium
- Copper
- Lead
- Mercury
- Zinc

➤ Problematic anions

- Ammonia
- Chloride
- Cyanide
- Nitrate
- Sulfate

Types of GW Contaminants

➤ **Pathogenic microorganisms**

✓ **Bacterial**

- **Cryptosporidium**
- **Salmonella typhi**

✓ **Parasitic / viral**

- **Giardia**
- **Hepatitis A**

Types of GW Contaminants

- **Radionuclides**
 - **Cesium 137**
 - **Radon 222**
 - **Radium 226 /228**
 - **Strontium 90**
 - **Uranium 235 / 238**

Sources of GW Contamination

Office of Technology (US Congress)

Classification

I. Sources designed to discharge substance

- ✓ Septic tanks, injection wells, land application

II. Sources designed to store, treat & / or dispose of substances

- ✓ Landfills, surface impoundments, mine waste, above ground storage tanks, USTs,

III. Sources designed to retain substances during transport

- ✓ Pipelines , material transport and transfer

Sources of GW Contamination

Office of Technology (US Congress)

Classification

- IV. Sources discharging substances as a consequence of other planned activities**
 - ✓ Irrigation, pesticide & fertilizer application, road salt, urban runoff, mine drainage

- V. Sources providing a conduit for contaminated water to enter aquifers**
 - ✓ Production, monitoring & exploration wells, construction excavation

- VI. Naturally occurring sources whose discharge is created by human activity**
 - ✓ GW/SW interaction, natural leaching, saltwater intrusion



*Most Common Sources of
GW Contamination in the West*

- **Agriculture**
- **Waste Disposal**
- **Mining**
- **Urbanization**

Ground-Water Management

- **16 Federal statutes that have provisions related to protection / restoration of GW quality**
- **Focus has been on contaminant source control & GW cleanup**
- **No Federal GW quality standards**
 - **SDWA MCLs – apply at the tap**
- **Source Water Protection / GW Rule – Federally mandated GW protection**

Ground-Water Management

- **GW quality management is State / County responsibility**
 - ✓ **With federal financial and technical assistance**
 - ✓ **Public health authority – County Health Dept.**
 - ✓ **GW Classification – in-situ standards**
 - ✓ **GW Discharge permits**

- **Past few years there has been a significant decline in emphasis on gw protection**
 - ✓ **Declining State budgets**
 - ✓ **Reduction in efforts at Federal level**

Ground-Water Management

Key Issues

- **GW management not aquifer based**
- **Highly fragmented, spread between many State, Federal and local agencies – conflicting responsibilities**
- **Inadequate recognition of GW/SW connections and impacts of drought**
- **Poor coordination between water supply & water quality management:**

Ground-Water Management

Key Issues

- **Many surficial, unconsolidated aquifers in the western USA have been contaminated.**
 - ✓ **This has led to increased development of deeper aquifers.**
- **These contaminated aquifers are a source of contamination to streams (TMDL issue)**
- **Non-point source contamination of ground water is still a significant problem (urban runoff, ag chemicals)**

Ground-Water Management

Key Issues

➤ Ground –Water Monitoring

- ✓ Woefully inadequate – victim of budget cuts**
- ✓ Aquifer based GW monitoring is needed**
- ✓ USGS / State Geol. Surveys should take lead**



What can be done?

- **Ground-Water Protection Strategy Workgroup**
 - EPA / State DEQ/ State AG Dept / USGS/ Tribes
 - **Mission – develop a strategy for refocusing & strengthening GW protection /management programs**
 - **Prevention of gw contamination STILL more effective than cleanup**



EPA Publications:

- I. Protecting the Nation's GW: EPA's Strategy for The 1990s**
- II. 2003 Ground Water Report to Congress**
- III. Ground Water in Region 8 States:
"A Report on the Status of Ground Water Management and Protection"**