COMMUNITY WATER CENTER
EL CENTRO COMUNITARIO POR EL AGUA

Stanford
SCHOOL OF EARTH, ENERGY & ENVIRONMENTAL SCIENCES

Groundwater Quality in the Sustainable Groundwater Management Act (SGMA):

Scientific Factsheet on Arsenic, Uranium, and Chromium

Groundwater is an important resource that we depend on to drink, bathe, grow food, and more. Through the implementation of the Sustainable Groundwater Management Act (SGMA) local groups called Groundwater Sustainability Agencies (GSAs) are developing Groundwater Sustainability Plans (GSPs) that indicate how they will manage groundwater in their area. One requirement of the Groundwater Sustainability Plans is to *"avoid significant and unreasonable degradation of groundwater quality"* (Water Code Section 10721(x)(4)).

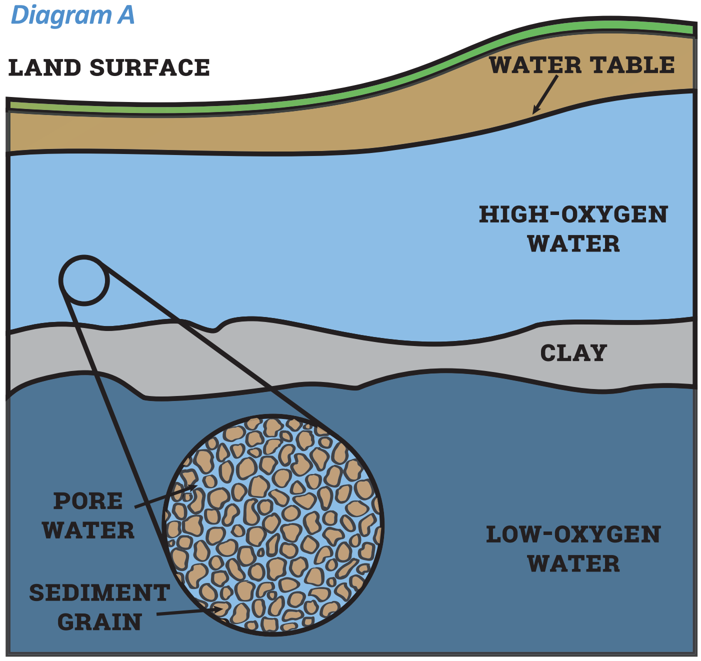
Groundwater can become contaminated through the use of human-made chemicals, fertilizers, or improperly managed waste facilities. Groundwater contamination can also occur naturally from elements in soils and sediments **(See Box 1)**. Some elements naturally present in rocks are toxic and harmful to health when they are dissolved in water, sometimes even at low concentrations. The most widespread of these metals are **arsenic** and **uranium**. **Chromium** is also of concern, primarily in a specific form (hexavalent chromium).

This factsheet explains how three elements — arsenic, uranium, and chromium — enter groundwater from soils and sediments, and how to address these already present impacts and work to prevent, limit, or reverse issues related to these contaminants. If you know these contaminants are present in your groundwater basin, we recommend you encourage your Groundwater Sustainability Agency to invest in additional monitoring and management practices to keep from worsening the problem. This factsheet provides illustrations based on recent scientific research to inform the design of those monitoring and management programs. For more information about best management practices for addressing drinking water in Groundwater Sustainability Plans, review Community Water Center's ***Protecting Drinking Water Under SGMA Guide***.

What Is Groundwater? How Can Naturally Occurring Metals Like Arsenic and Uranium Enter Groundwater?

Groundwater is water that exists below the earth's surface, either in the space between grains of sand, gravel, and clay, or in the fractures of solid rocks. The layers of rock and sand that contain groundwater are called aquifers ***(Diagram A)***. Underground sediments and rocks contain many different minerals and metals, either attached to the surface of the grain, or as part of the sediment/rock itself. Under certain conditions, these minerals and metals can move into the groundwater, or become dissolved.

Diagram A



There are many conditions that affect and accelerate the movement of metals from rocks into groundwater including the pH (level of acidity) and the amount of dissolved oxygen in the water. Changes in pH and oxygen can lead to higher concentrations of dissolved metals in groundwater but each metal responds differently to these conditions.

Importance of Monitoring and Using Groundwater Information to Manage Groundwater Quality:

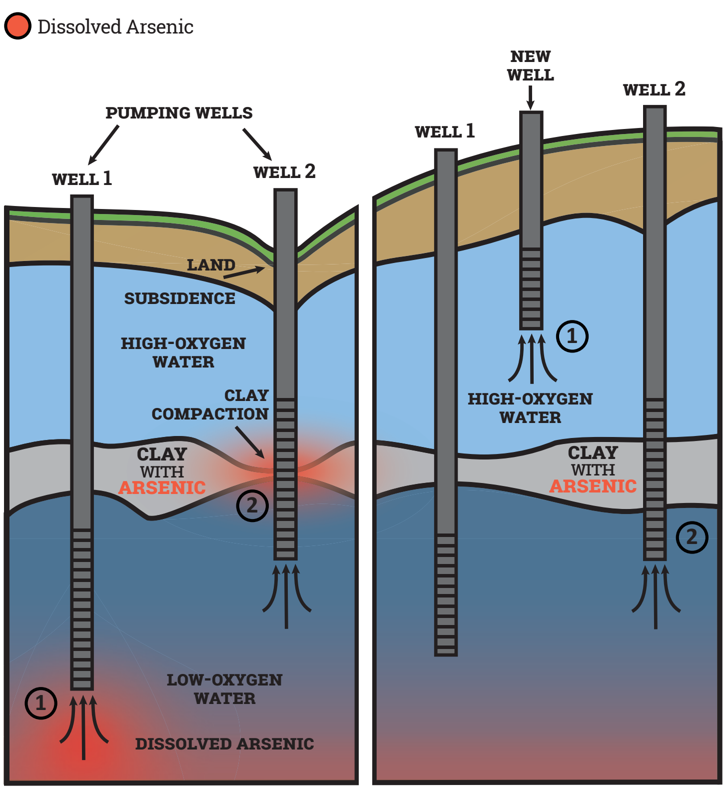
Many of the factors that cause naturally occurring contaminants to enter groundwater can be prevented or mitigated using a robust groundwater monitoring and information gathering strategy. Determining the best management technique often requires some trial-and-error. Recommendations include:

- Regularly measure levels of naturally occurring contaminants (arsenic, uranium, and chromium) in well as the conditions that can cause contamination (changes in pH, dissolved oxygen, nitrate, and electrical conductivity)
- Evaluate groundwater flow paths (for example, through the use of groundwater tracer tests) to know where contaminated water may travel over time, and use this information to strategically install monitoring wells that are upgradient of supply wells.
- Use well logs during well installation to ensure screen intervals are a maximum distance from clay layers.

ARSENIC *(Diagram B)*

PROBLEMS	SOLUTIONS
Low-oxygen conditions *(Diagram C)* When an aquifer becomes low in oxygen (~1% or lower dissolved oxygen), bacteria will dissolve the iron minerals that contain arsenic, and the arsenic itself will also change forms (from the molecule arsenate to arsenite). The outcome is an increase in dissolved arsenic in the groundwater. This is the most common cause of arsenic contamination of groundwater.	For a new well design or a well modification, avoid drawing groundwater from low oxygen zones if there is a concern about arsenic in that area.
Over-pumping Most wells draw groundwater from aquifers made of sand and gravel sediments, where water can be pumped out of the spaces between sediment grains. Aquifers can also have clay layers that may contain low-oxygen conditions and dissolved arsenic. When an aquifer is over-pumped, the clay layers can be compressed, squeezing the water with arsenic out from the clay and into the main aquifer.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
An increase in pH When the pH of groundwater goes above 8.5, arsenic is displaced from mineral surfaces and dissolves into the groundwater.	Limit drawing from groundwater with pH greater than 8.5.

Diagram B: Problems and Solutions



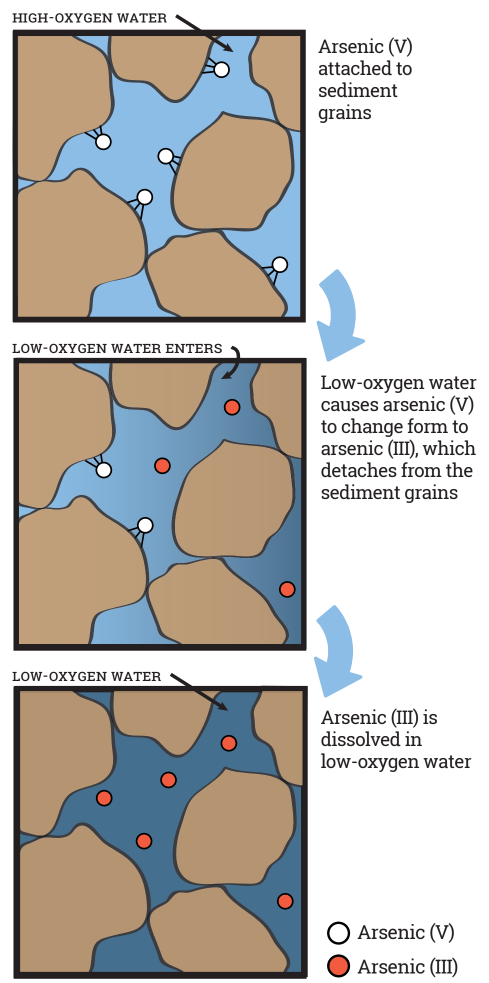
PROBLEMS

1. Low-oxygen conditions cause arsenic to dissolve into water pumped by Well 1.
2. Well 2 pumps at a high flow rate, causing the clay with arsenic to compact and high-arsenic pore water is "squished" out.

MANAGEMENT SOLUTIONS

1. New well drilled in an area with high-oxygen water and low dissolved arsenic.
2. Well 2 uses a lower flow rate, which stops high-arsenic water from coming out of the clay.

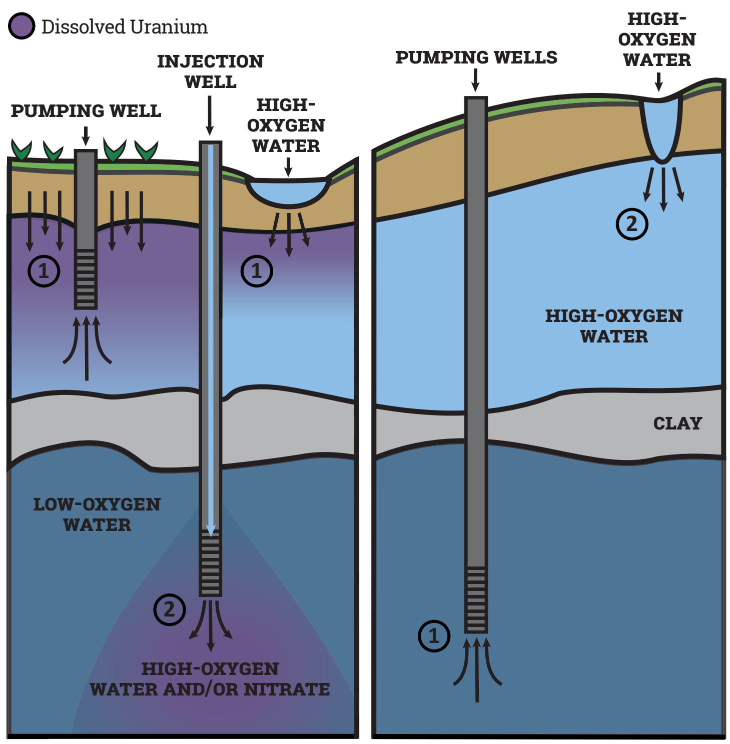
Diagram C: Arsenic dissolves in low-oxygen water (desorption)



URANIUM *(Diagram D)*

PROBLEMS *(Diagram E)*	**SOLUTIONS**
An increase in dissolved bicarbonate and calcium Uranium is often “stuck” (adsorbed) to the edges of sediments. When uranium comes into contact with dissolved bicarbonate and calcium, it can form large molecules that are easily dissolved, increasing uranium concentrations in groundwater. Bicarbonate and calcium are naturally present in soils and are usually more concentrated at the surface because of higher biological activity (plants and microorganisms) and evaporation. As a result, water percolating through the soils, will increase in calcium and bicarbonate, which increases dissolved uranium concentrations as well.	Natural infiltration through soil from rain or drip irrigation cannot be avoided. However, if uranium is present in the proposed recharge area, managed aquifer recharge (MAR) should limit percolation through soil with high bicarbonate and/or calcium content. If there are high levels of bicarbonate or calcium in the upper layers of the soil, using recharge ponds or ditches/canals excavated through the soil (~6 to 8 ft deep) may prevent uranium contamination.
An increase in nitrate or high-oxygen conditions When uranium is present in low-oxygen conditions, it does not dissolve into groundwater. However, when nitrate or high-oxygen water enter the aquifer, they can react with uranium and change it into a form that readily dissolves, increasing uranium concentrations in groundwater.	Avoid over-pumping from confined aquifers to the point of clay compression (subsidence). Avoid drilling wells in aquifers with high clay content, or where pumped water may draw from clays containing arsenic.
Drawdown of shallow groundwater Dissolved uranium concentrations are often higher in shallow groundwater, where there are high-oxygen conditions and more dissolved bicarbonate and calcium. High rates of pumping in deep wells may draw down this shallow water, increasing the amount of dissolved uranium in extracted water.	Monitor uranium content and prevent drawdown of shallow, uranium-rich groundwater by reducing pump rates or promoting injection wells as necessary.

Diagram D: Problems and Solutions



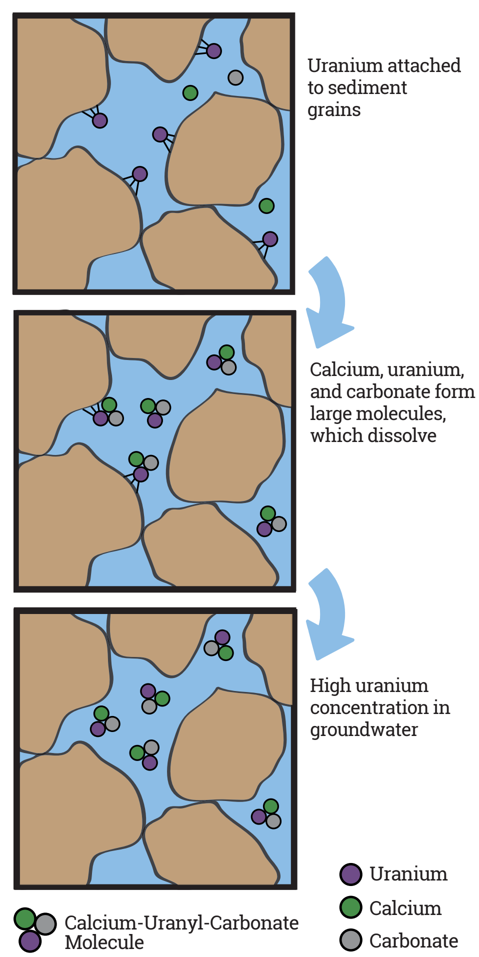
PROBLEMS

1. Recharge through vegetated area and infiltration pond leads to an increase in bicarbonate and calcium, which causes uranium to dissolve.
2. Injection well introduces high-oxygen water or nitrate, releasing uranium.

MANAGEMENT SOLUTIONS

1. Well pumps water from deeper aquifer without bicarbonate and calcium.
2. Managed aquifer recharge through excavated ditch prevents uranium contamination.

Diagram E: Uranium dissolves as part of molecule



Arsenic and Uranium, Combined Management

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Maintain pH below 8.5 to limit dissolved arsenic. If pH exceeds 8.5, more investigation is necessary.
- If uranium is present in oxygen-rich zones, keep calcium and bicarbonate concentrations low to help to keep it out of the water.
- Prevent high rates of pumping that draw uranium from shallow groundwater or arsenic from low-oxygen zones.
- Monitor levels of arsenic, uranium, dissolved oxygen and oxidation-reduction potential (ORP) in groundwater. If arsenic concentrations increase, the aquifer may be low in oxygen. If uranium concentrations increase, the aquifer may be too oxygenated.
- For recharge project recommendations, please consult CWC's Protecting Drinking Water Under SGMA Guide.

What about CHROMIUM?

When dissolved arsenic and uranium are both present in groundwater, certain management practices can help to reduce concentrations of both elements:

- Increased groundwater pumping and fluctuations in groundwater levels;
- High-oxygen conditions at the surface generate hexavalent chromium, which is pulled down into the aquifer through recharge or pumping;
- Naturally occurring manganese converts trivalent to hexavalent chromium.

More research is needed to determine the best way to minimize hexavalent chromium production and concentrations in groundwater. Where active recharge is being conducted, following strategies for uranium mitigation is likely the best practice.

GLOSSARY:

- **Adsorbed:** "Stuck" to the edges of sediments.
- **Dissolved:** In liquid form; part of the groundwater.
- **High-oxygen and low-oxygen:** Conditions that reflect how much oxygen is dissolved into groundwater. High-oxygen conditions are sometimes called "aerated", while low-oxygen (~1% or lower dissolved oxygen) is called "reduced".
- **pH:** A measure of the acidity of the water. Groundwater pH is generally between 6.5 and 8.5. Water with lower pH is more acidic, while higher pH indicates alkaline (basic) conditions.
- **Naturally occurring:** Present within the rocks that make up the aquifer; not due to human activity.

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