MODERN IN SITU URANIUM RECOVERY TECHNOLOGY ASSURES NO ADVERSE IMPACT ON ADJACENT AQUIFER USES

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In-situ recovery ("ISR") is an noninvasive mining process where uranium is extracted from sandstone aquifers by reversing the natural process which deposited the uranium. Existing groundwater fortified with oxygen is used to leach the uranium from sands. The uranium is then recovered by passing the leach solution over ion exchange resin, much like in a domestic water softener. The loaded resin is then processed. Finally, the groundwater is restored consistent with its previous quality and use.
**O₂ INJECTION/CARBONATE COMPLEX**

**U4 to U6**

\[ 2\text{UO}_2 + \text{O}_2 \rightarrow 2\text{UO}_3 \]

\[ \text{UO}_3 + 2\text{NaHCO}_3 \rightarrow \text{NA}_2\text{UO}_2(\text{CO}_3)_2 + \text{H}_2\text{O} \]
**INCREASE TRACE ELEMENTS/SALINITY**

**Oxidation, pH↓ and Ion Exchange**

**Oxidation of iron sulfides** – Fe (ppt) \( \text{SO}_4 \uparrow \text{pH} \downarrow \)
\[
\text{FeS}_2 + 15/4 \text{O}_2 + 7/2 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 \text{[ppt]} + 4 \text{H}^+ + 2 \text{SO}_4 = 
\]

**Oxidation of ferroselite** – Fe (ppt) Se \( \uparrow \text{pH} \downarrow \)
\[
\text{FeSe}_2 + 11/4 \text{O}_2 + 7/2 \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 \text{[ppt]} + 4 \text{H}^+ + 2 \text{SeO}_3 = 
\]

**Oxidation of molybdenum sulfide** – Mo \( \uparrow \text{S} \uparrow \text{pH} \downarrow \)
\[
2 \text{MoS}_2 + 9/2 \text{O}_2 + 2 \text{H}_2\text{O} \rightarrow \text{Mo}_2\text{O}_5 + 4 \text{H}^+ + 2 \text{S}_2\text{O}_3 = \text{Thiosulfate} 
\]

**Dissolution of calcium carbonate from lowered pH caused by oxidation of one mole of FeS\(_2\) – CaSO\(_4\) (ppt) HCO\(_3\) \( \uparrow \text{pH} \uparrow \)**
\[
[\text{Ca} \uparrow \text{further lowers CaSO}_4 \text{ & HCO}_3 \text{ solubility}] 
2 \text{H}_2\text{SO}_4 + 4 \text{CaCO}_3 + 4\text{NaCl} \rightarrow 4\text{NaHCO}_3 + 2 \text{CaSO}_4 \text{[ppt]} + 2 \text{Ca}^{++} + 2 \text{Cl}^- 
\]
ION EXCHANGE (IX)

\[ \text{Na}_2\text{UO}_2(\text{CO}_3)_2 + 2\text{RCl} \rightarrow \text{R}_2 \text{UO}_2(\text{CO}_3)_2 + 2\text{NaCl} \]
NO REGIONAL AQUIFER IMPACT

ISR is performed only in the localized mineralized zone of the aquifer.

1. Wellfield patterns are engineered, balanced, a negative production bleed is maintained and the ore zone is surrounded by horizontal and vertical monitor wells.

2. Before monitoring ceases, restoration must be completed.
Naturally - uranium and its decay products, radium and radon, cause groundwater to become radioactive and to exceed federal and state drinking water limits making the natural groundwater present with uranium ore and suitable only for industrial purposes.
NATURAL URANIUM CONCENTRATION BEFORE MINING

- Rosita Location
- Vasquez Location
- EPA Drinking Standard

Parts Per Billion

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<thead>
<tr>
<th>Location</th>
<th>Parts Per Billion</th>
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<tr>
<td>Rosita Location</td>
<td>800</td>
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<td>EPA Drinking Standard</td>
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RADIUM CONCENTRATION BEFORE MINING

Rosita Location
Vasquez Location
EPA Drinking Standard

Parts Per Trillion

Uranium Resources
RADON CONCENTRATION BEFORE MINING

Vasquez Location

300 Parts Per Trillion

EPA Drinking Standard
RESTORATION/RECLAMATION REGULATIONS

1. Groundwater Restoration
   (30TAC331.107)

2. Plugging and Abandonment of Wells
   (30TAC331.86)
GROUNDWATER RESTORATION

REPLACE THE PRODUCTION PLANT WITH A RESTORATION PLANT
WASTE DISPOSAL

Uranium Resources
RESTORATION VALUES NOT ACHIEVED

331.107(f) the commission will consider the following:

1. uses for which the groundwater was suitable at baseline water quality levels;

2. actual existing use of groundwater in the area prior to and during mining;

3. potential future use of groundwater of baseline quality and of proposed restoration quality;

4. the effort made by the permittee to restore the groundwater to baseline;

5. technology available to restore groundwater for particular parameters;

6. the ability of existing technology to restore groundwater to baseline quality in the area under consideration;

7. the cost of further restoration efforts;

8. the consumption of groundwater resources during further restoration; and

9. the harmful effects of levels of particular parameter.
INCREASE TRACE ELEMENTS

Oxidation

**Oxidation of iron sulfides** – \( SO_4 \uparrow \)
\[
\text{FeS}_2 + \frac{15}{4} \text{O}_2 + \frac{7}{2} \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 \text{[ppt]} + 4 \text{H}^+ + 2 \text{SO}_4^-=
\]

**Oxidation of ferroselite** – \( \text{Se} \uparrow \)
\[
\text{FeSe}_2 + \frac{11}{4} \text{O}_2 + \frac{7}{2} \text{H}_2\text{O} \rightarrow \text{Fe(OH)}_3 \text{[ppt]} + 4 \text{H}^+ + 2 \text{SeO}_3^-=
\]

**Oxidation of molybdenum sulfide** – \( \text{Mo} \uparrow \)
\[
2 \text{MoS}_2 + \frac{9}{2} \text{O}_2 + 2 \text{H}_2\text{O} \rightarrow \text{Mo}_2\text{O}_5 + 4 \text{H}^+ + 2 \text{S}_2\text{O}_3^-=
\]

Thiosulfate

**Oxidation of UO\(_2\)**
\[
2\text{UO}_2 + \text{O}_2 \rightarrow 2\text{UO}_3
\]
\[
\text{UO}_3 + 2\text{NaHCO}_3 \rightarrow \text{Na}_2\text{UO}_2(\text{CO}_3)2 + \text{H}_2\text{O}
\]
ATTENUATION / DISPERSION

Water OK

TOXIC Water

OXIDIZED

REDUCED

URANIUM ROLL FRONTS
ATTENUATION / DISPERSION MITIGATE

1. Premining contamination from uranium, radium and radon make the water undrinkable using EPA standards.

2. The ore deposit can be millions of years old with billions of gallons of groundwater having moved through the area, but water analysis shows that because of attenuation and dispersion the contamination remains confined to the uranium mineralization.

3. This process is active today. Roll fronts require broad areas of up gradient meteoric oxidation to keep uranium mobile until that oxidized water moves downgrade far enough to encounter a zone of abundant reductant.

4. The ore area is extremely small compared to the size of the regional aquifer so logically the regional reducing capacity of the aquifer will prevail over small pockets of residual oxidation.

5. It is unreasonable to conclude that a regional geologic formation maintains the capacity to absorb meteoric oxygen from expanses of slow moving ground water on a grand scale with resulting regional precipitation of metals, yet this same redox interface would be unable to absorb a far smaller amount of manually injected oxygen from equally slow moving post-restoration groundwater from an ISR operation and precipitate the very same metals in similar concentrations.
REDUCTION/BIOREMEDIATION

1. Reducing Agents

2. Nutrient Supplement

3. Hydrogen Injection
PLUGGING AND ABANDONMENT
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