



Selenium Pilot Bioreactor Results

BUREAU OF RECLAMATION SCIENCE AND TECHNOLOGY PROGRAM

Project No. 4414.

Presented by,

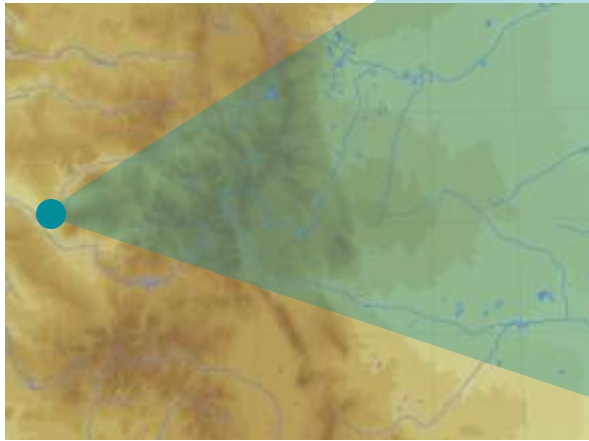
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Site Details



- Location - United Sand and Gravel Pit adjacent to Colorado River in Grand Junction, Colorado
- Bench testing on site Summer 2006 through Spring 2007 with funding from Bureau of Reclamation
- Source water is gravel pit dewatering trench





Pilot Test Goals

Pilot Test Goals –

- demonstrate high-efficiency selenium removal at the pilot scale
- determine the relationship between selenium removal efficiency and detention time
- assesses the influence of seasonal temperature fluctuations on treatment performance
- determine design parameters for a full-scale system



Construction, July 2008

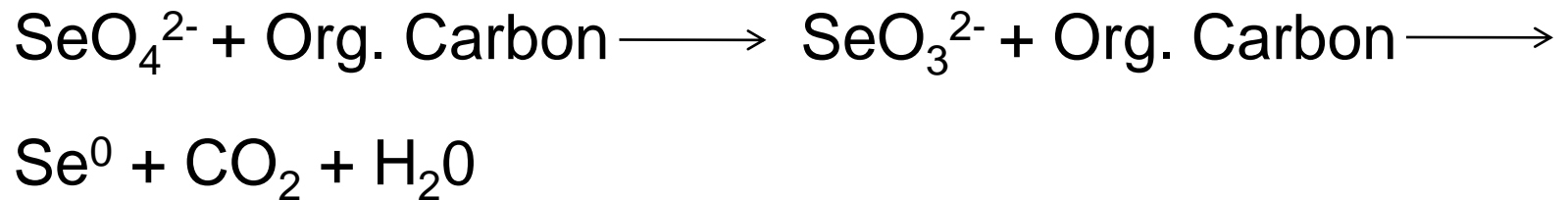
- Downward flow vertical biochemical reactor (BCR)
- Solid phase media: 30% sawdust, 30% wood chips, 20% limestone, 10% hay, 10% cow manure
- Design flow rate of between 3 and 15 gpm
- Began treating water September 10, 2008





BCR Selenium Removal

- Selenium removal – dissimilatory microbial reduction of dissolved species (i.e., selenite, selenate)



- Selenium is precipitated within the BCR -



Construction





Construction

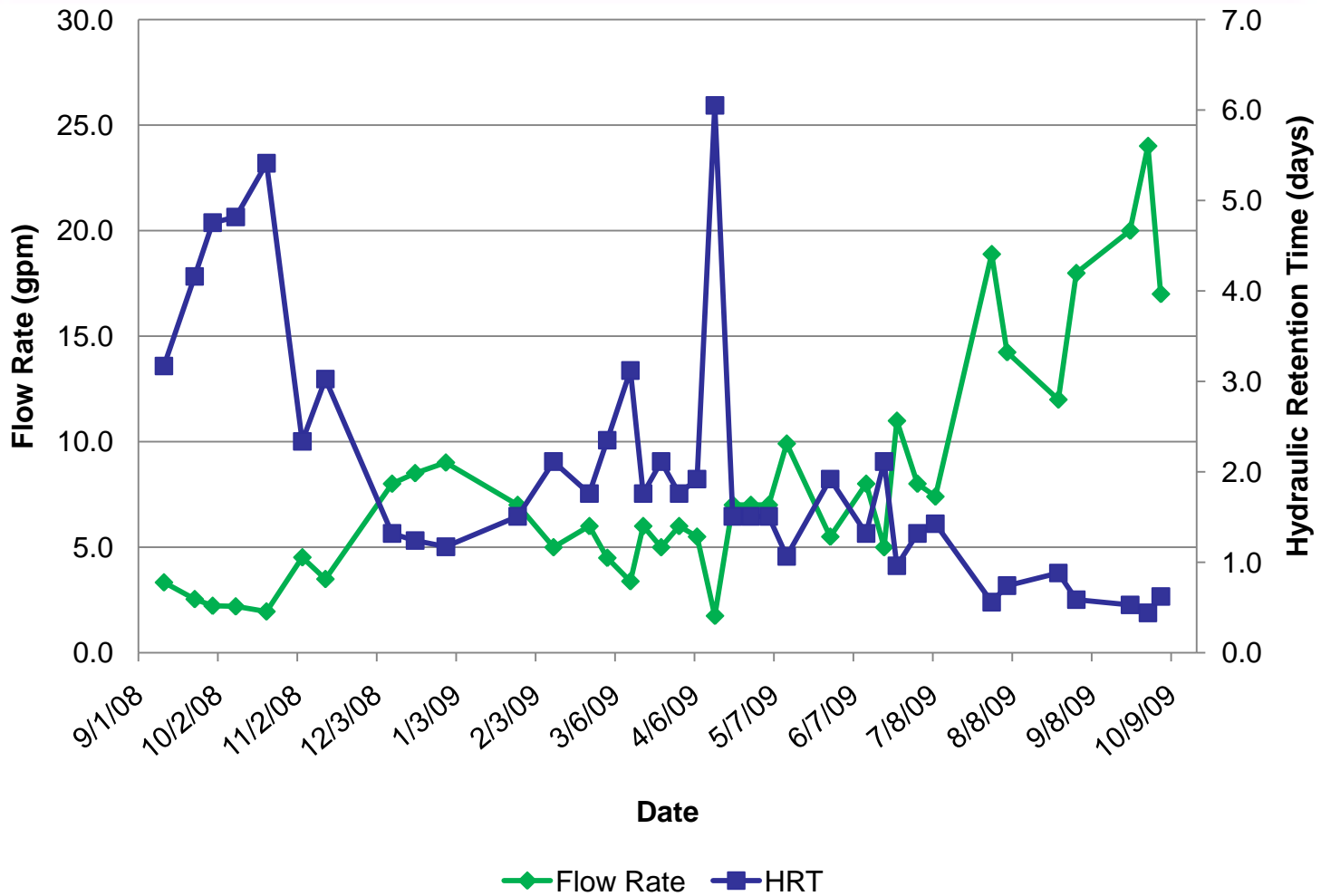


- Negatives – pump issues, cell flooding
- Positives – no freezing issues, relatively continuous operation



Treatment Results – Flow Rate

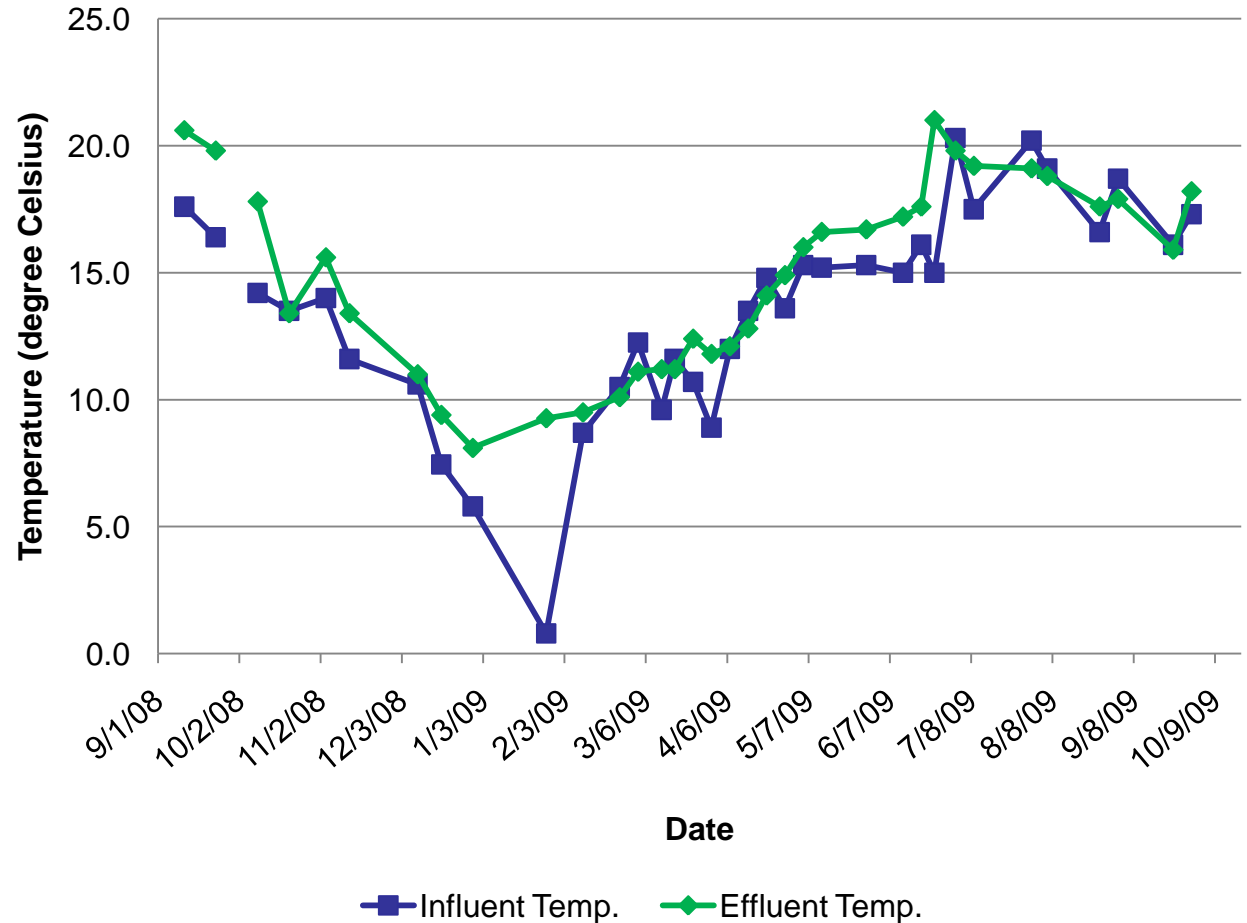
- Flow ranged from 1.7 to 24 gpm
- HRT ranged from 0.4 to 6 days





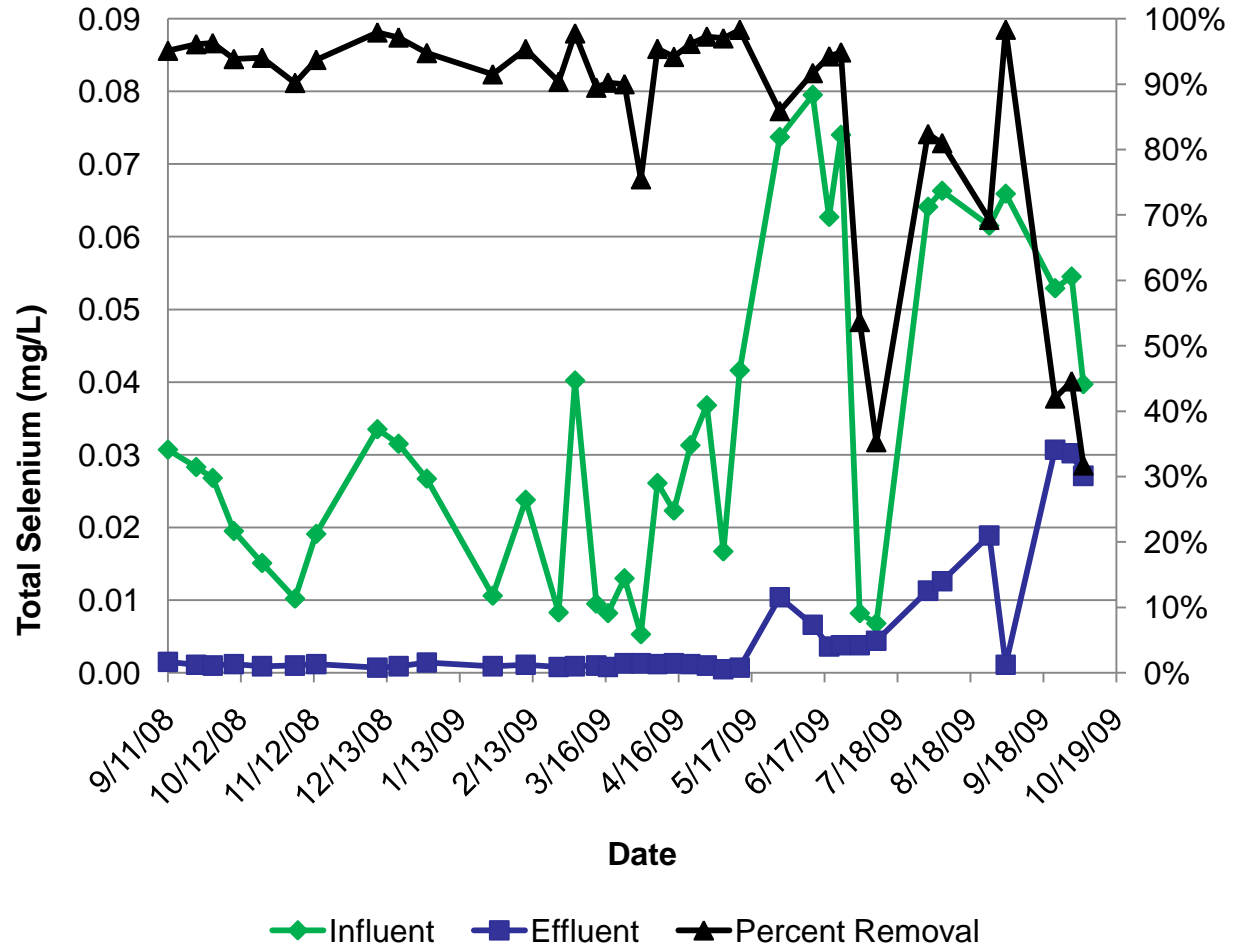
Treatment Results - Temperature

- Minimum influent temperature 0.8° C
- Influent temp remains relatively warm in winter-groundwater influence



Treatment Results – Total Selenium

- Influent has ranged from 5 to 80 $\mu\text{g/L}$
- Effluent has averaged 1 $\mu\text{g/L}$ – always below 5 $\mu\text{g/L}$
- Influent source was changed to increase influent selenium concentrations
- Cold winter did not decrease removal rates





Treatment Results –

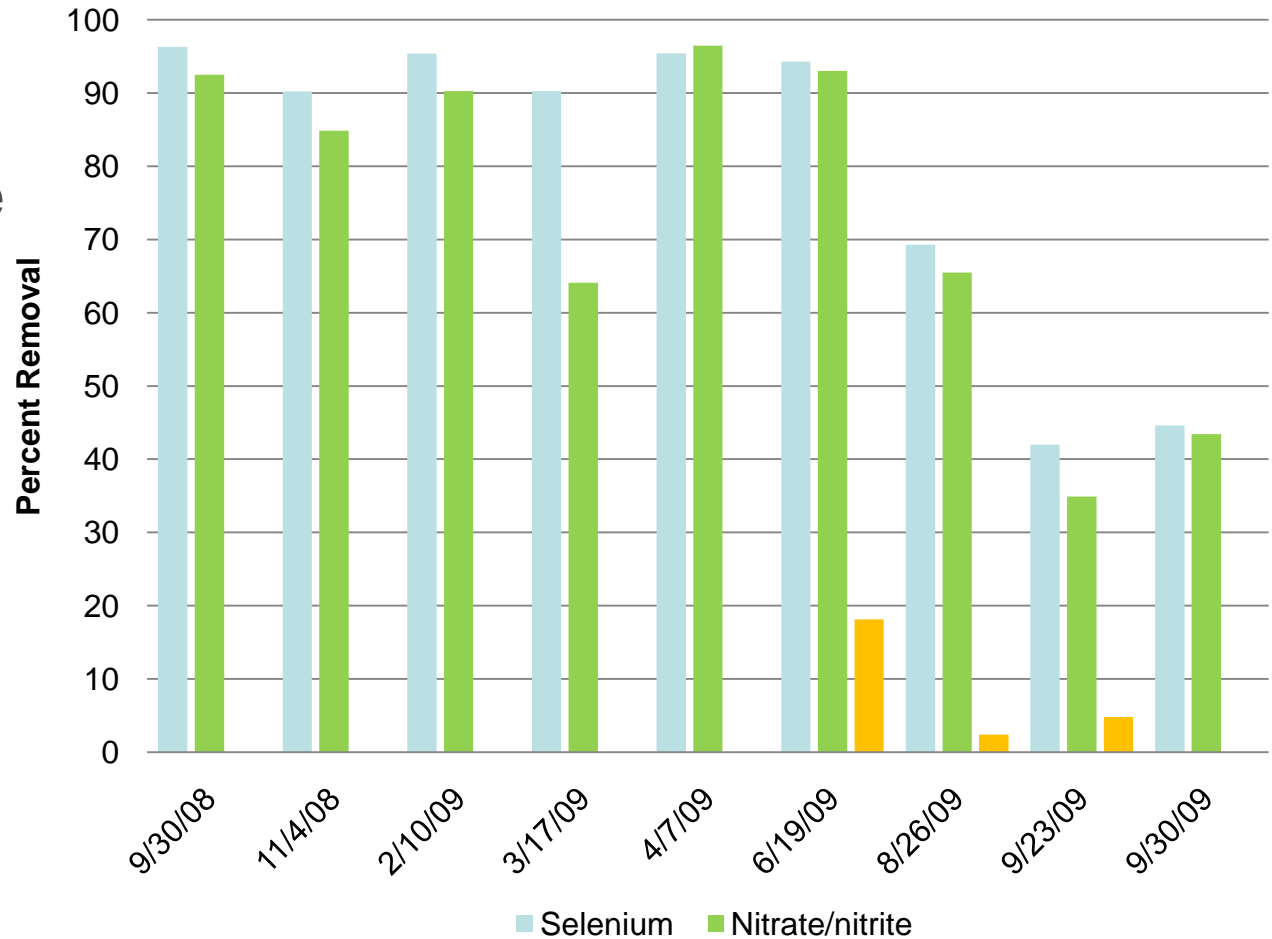
- Influent concentrations of NO_3 and selenium are variable – difficult to get good loading data

	Influent	Effluent
	Total Selenium	
	ug/L	
Minimum	5.3	0.5
Maximum	79.5	30.7
Average	33.6	5.1
	Nitrate + nitrite	
	mg/L as N	
Minimum	0.4	0.1
Maximum	17.1	9.7
Average	7.1	3.1



Treatment Results – Se, NO₃, SO₄ removal

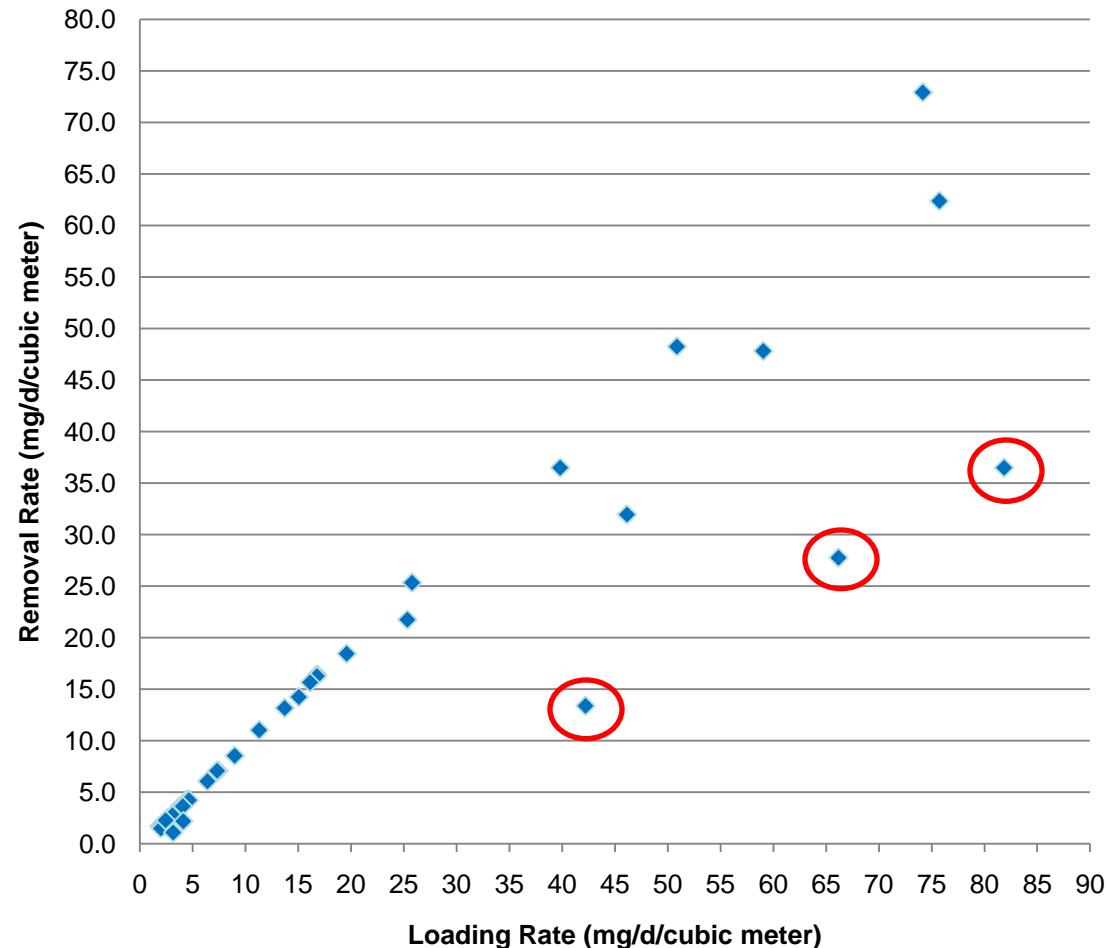
- Nitrate is removed before selenium
- Sulfate removed after selenium



Note: Sulfate removal prior to 6/19/09 is not included due to laboratory analytical issues.

Treatment Results – Selenium Loading

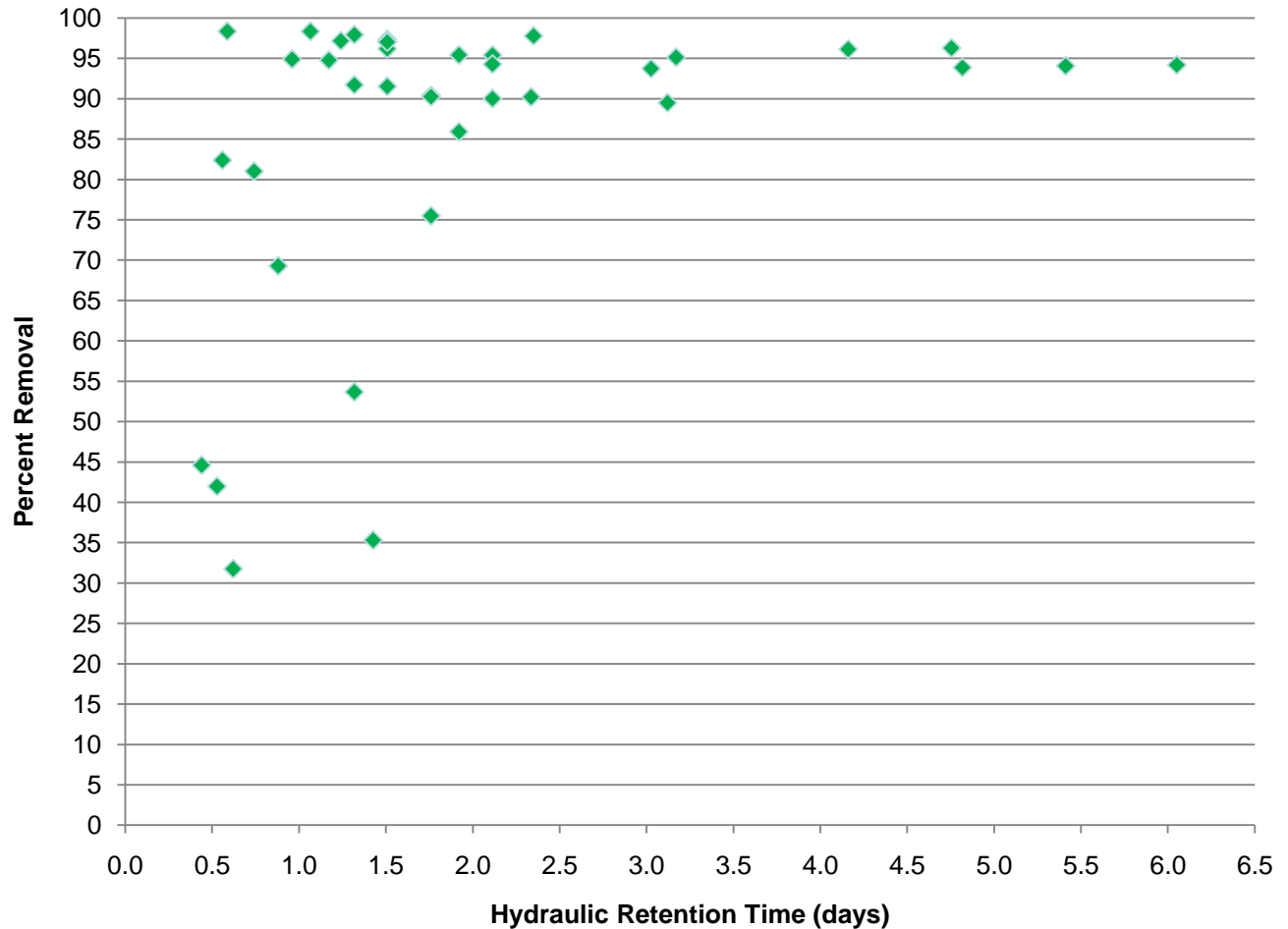
- Selenium loading and removal (mg/day/cubic meter)
- Temperature and nitrate likely responsible for variation



Treatment Results –

- Selenium percent removal vs. HRT

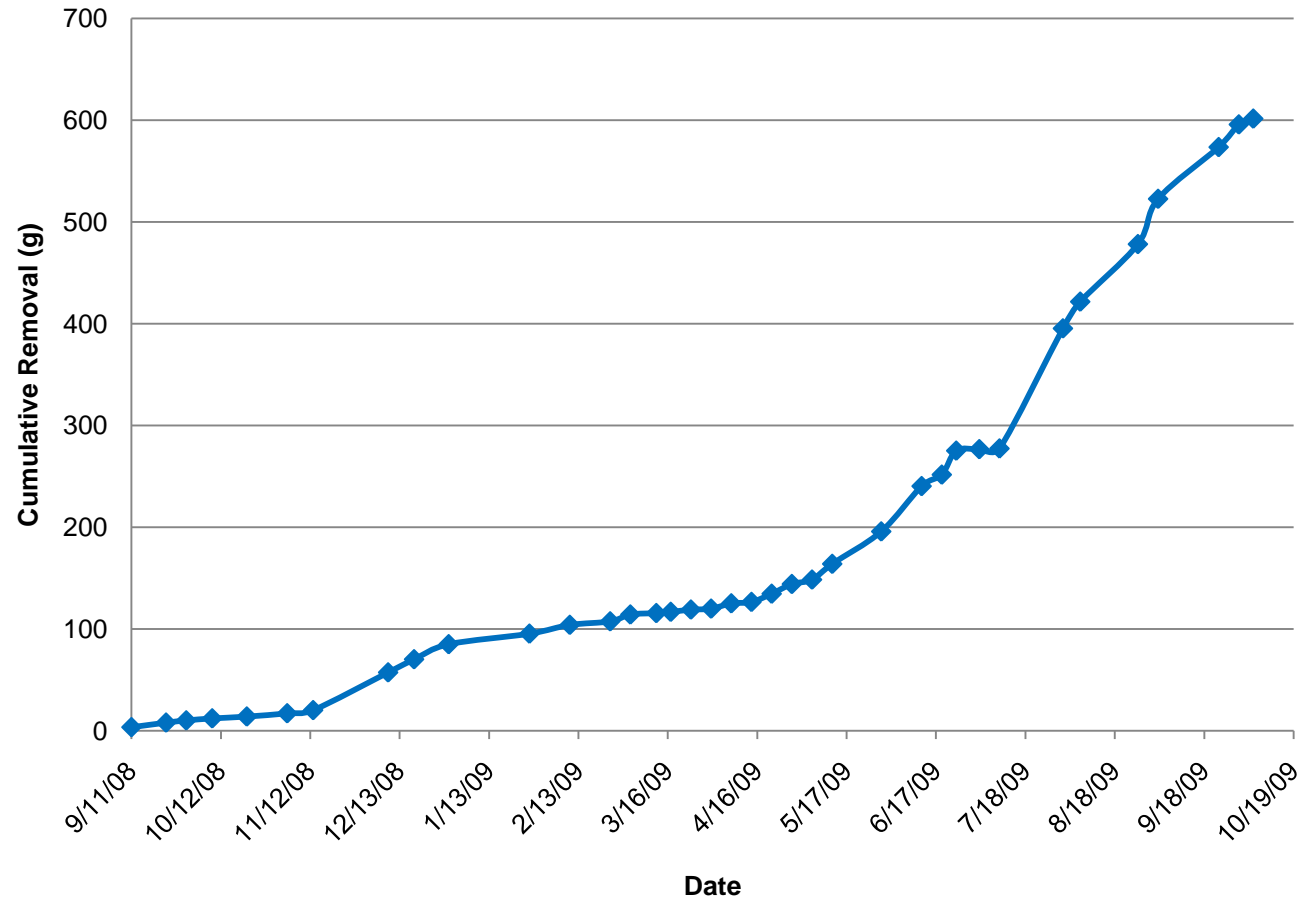
- Lots of disagreement with less than 1.5 days HRT





Treatment Results –

- 600 grams of selenium removed during pilot testing



SITE-SPECIFIC CONCLUSIONS

- BCR effective at removing Se to as low as 0.5 µg/L and a maximum removal rate of 98%.
- Max selenium removal was 73 mg/day/m³
- Nitrate may be more effective design parameter (loading rate of 10 g/d/m³)
- 2 day HRT is recommended to consistently achieve >90% removal rates
- BCR effective in winter months
- Substrate passed TCLP

Pilot Costs

- Total capital cost \$39,200 (\$15,000 for engineering, \$8,000 for materials, and \$15,700 for labor)
- Equates to \$4,400 per kilogram of selenium (Assuming 10 gpm and 15 years of operation)
- Operation and maintenance costs are minimal

Full-Scale Costs

Assumptions:

1-acre surface footprint

Cost of aerobic polishing, land acquisition are not included

2 day HRT (will vary by site)

225 gallons per minute (1 acre-ft per day)

Influent selenium of 35 µg/L, 90% selenium removal rate

- Rough order-of-magnitude capital cost is \$900,000
- System would remove 14 kg of selenium per year.



BCR Full-Scale Costs

Active Microbial Reduction Case Study Details

Source	Description	Scale	Length of Operation	Location	Flow Rate	Cost (USD)	Reference
Agricultural	Upflow Anaerobic Sludge Blanket Reactor (UASBR)	Pilot	2 yr	California	NA	Operating: \$1.23-1.48/1,000 gal (2005 dollars)	Owens 1998
MIW	Anaerobic fixed film bioreactor using activated carbon support	Full Scale	2 yr, ongoing	Goldcorp's former Wharf Resources Mine, Lead, SD	40-300 US gpm	Capital: \$1 million Operating: \$0.57/1,000 gal (2005 dollars)	Microbial Technologies 2005
MIW	Anaerobic fixed film bioreactor using activated carbon support	Full Scale	NA, ongoing	Zortman-Landusky gold mine, MT	75-300 US gpm	Capital: \$3 million Operating: \$2.38/1,000 gal (2000 Dollars)	Microbial Technologies 2005
Flue-Gas Desulfurization	GE ABMet®	Full Scale	9 mo, ongoing	Progress Energy Roxboro Station	1400 US gpm	NA	Sonstegard et al. 2008
MIW	Anaerobic fixed film bioreactor using high surface area media support	Full Scale	2 yr, ongoing	Undisclosed gold mine, Western US	250 US gpm	Operating: \$5.71/1,000 gal (2008 dollars)	Gusek et al. 2008

Note: MIW - mining influenced water.
NA - information is unavailable

Golder, 2009. Literature Review of Treatment Technologies to Remove Selenium from Mining Influenced Water. Available at <http://namc.org/selenium.html>



Acknowledgements –

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