THE UNIVERSITY OF UTAH™

TOGETHER WE REACH

DEPARTMENT OF METALLURGICAL ENGINEERING

ELECTROBIOCHEMICAL REACTOR (EBR): METALS, NITRATE & BOD

D. Jack Adams, Ph.D.

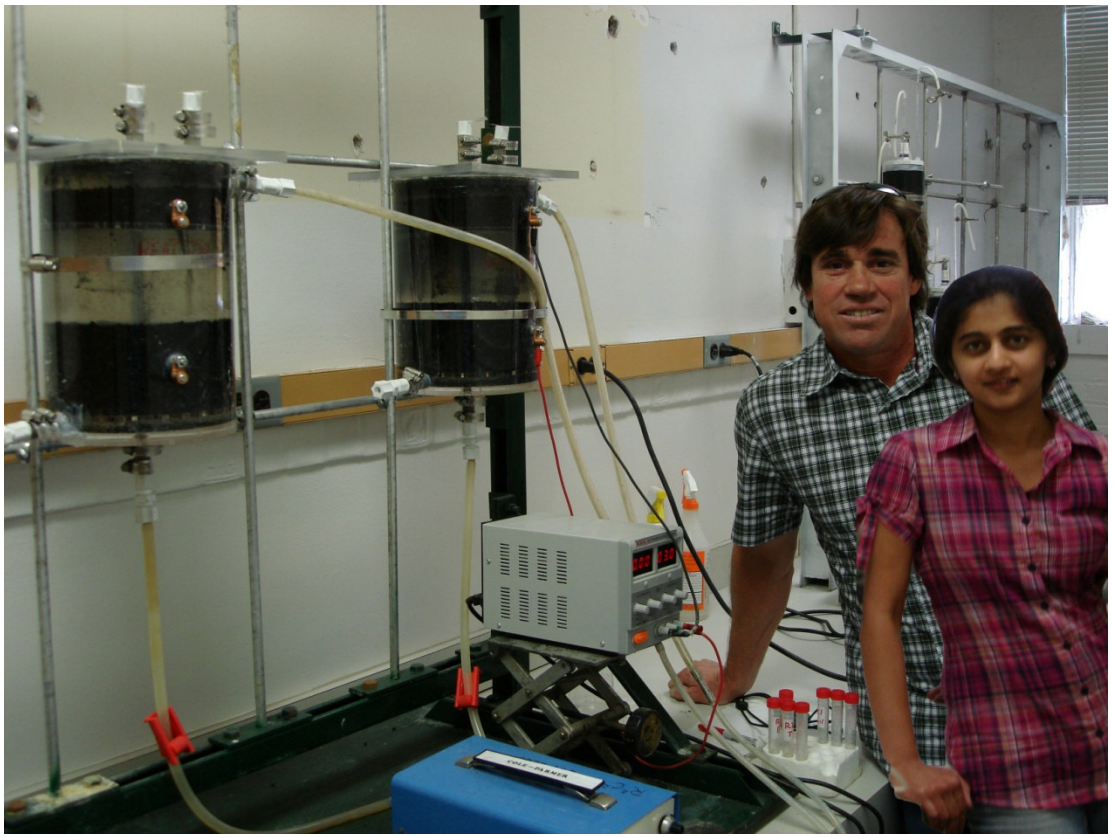
Mike Peoples

Nicol Newton

Madhuri Nanduri

GRADUATE STUDENTS

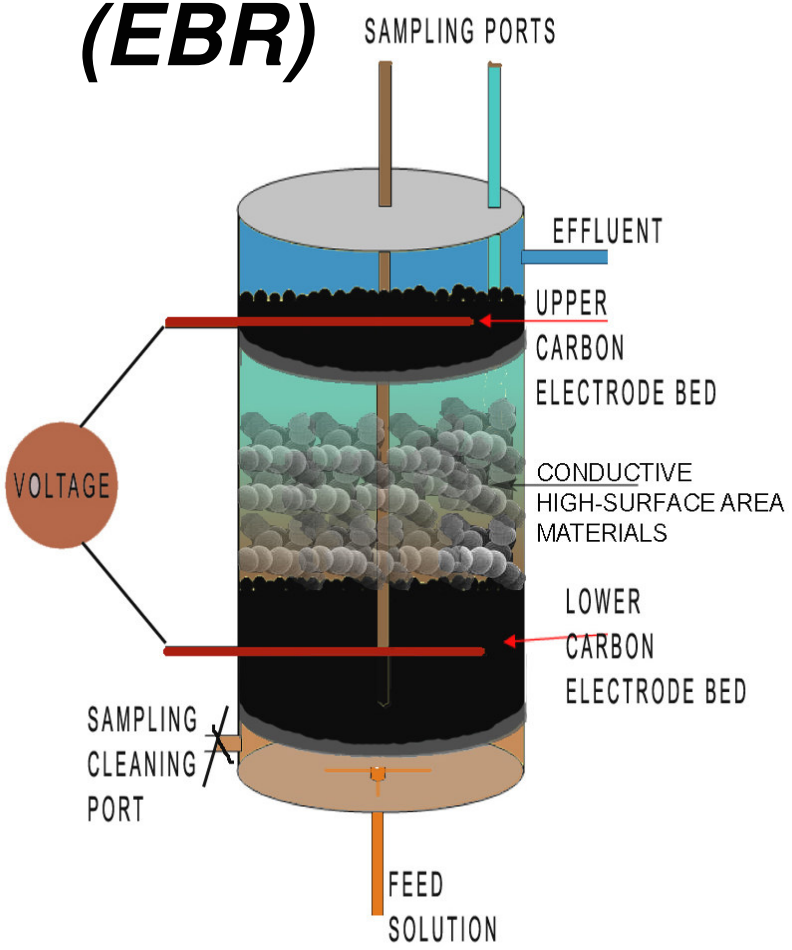
- Mike Peoples
- Madhuri Nanduri



OUTLINE

- ELECTROBIOCHEMICAL REACTOR – EBR TECHNOLOGY
  - Patented bioreactor and surface optimization technologies
  - Combination of classical bioreactors and applied potential
  - Low voltage requirements
- METAL REMOVAL TESTS
  - Microbial Screening
  - Batch tests for optimizing contaminant removals
    - Arsenic, selenium, mercury, nitrates
  - Extended dynamic testing
  - BOD removal
- SUMMARY

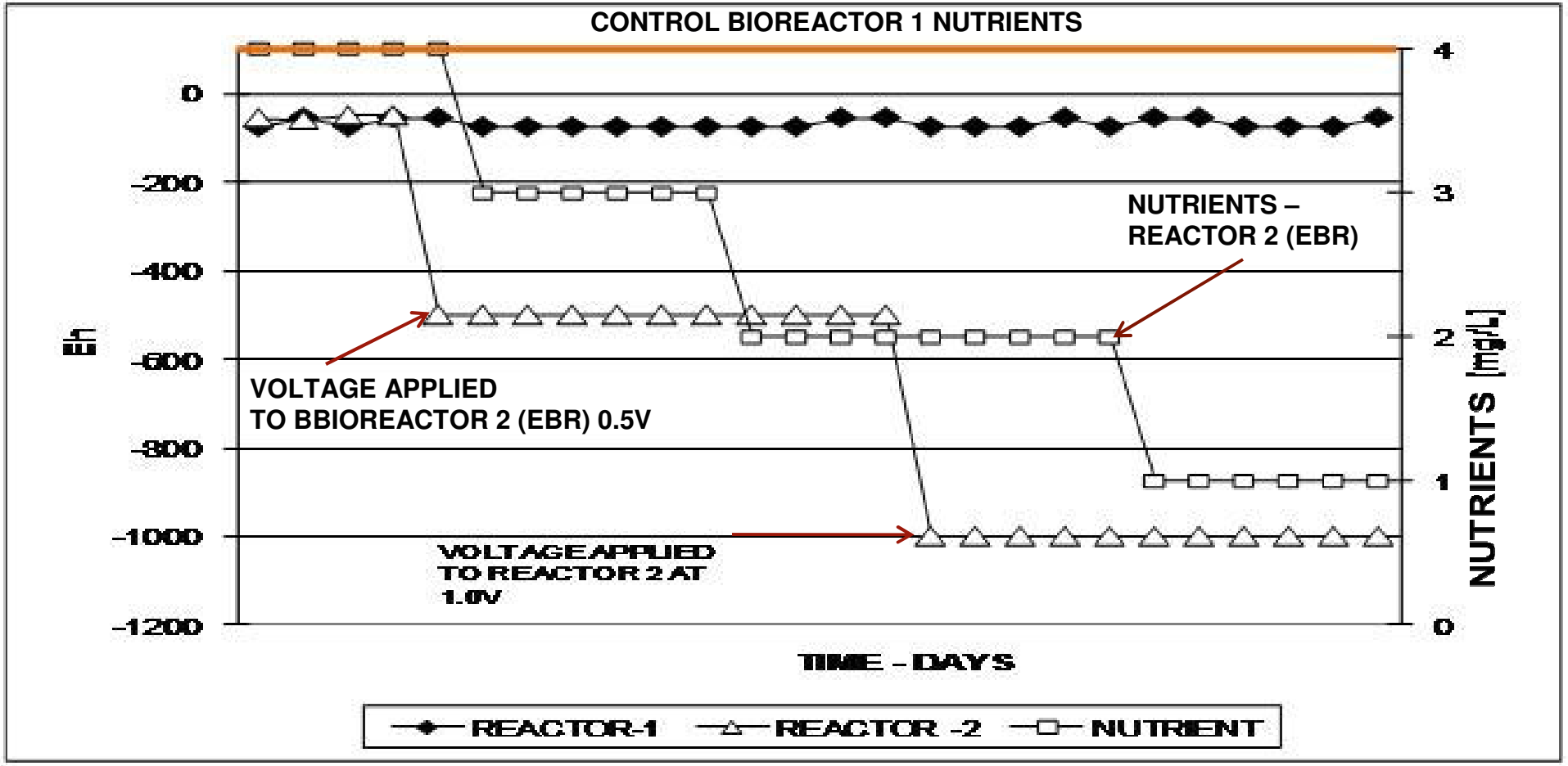
ELECTROBIOCHEMICAL REACTOR (EBR)



- Reduces system ORP and reduces the use of nutrients to lower ORP
  - Reduces nutrient costs
- Supplies some of the energy (electrons) required for bacterial growth
  - Reduces nutrient costs
- Supplies energy potential for contaminant transformation
  - Reduces contaminant transformation energies
  - Reduces microbial energy requirements for contaminant transformation
  - Improves contaminant transformation kinetics

LOW VOLTAGE BIOREACTORS – 0.05 TO 3 VOLTS

ORP/NUTRIENT/VOLTAGE TESTS



ORP/NUTRIENT/VOLTAGE CONCLUSIONS

- Low voltage can be used to adjust ORP instead of nutrients – less nutrients will be required for bioreactor operation
  - Voltage required isdependent on bioreactor microbial support materials, water chemistry, and microbes
- Supplied voltage provides electrons at the bacterial surface provides a readily available supply of elections to the bacterial/ contaminant/surface environment - appears to lower the bacterial contaminant interaction and transformation energy requirements
- Supplied voltage provides electrons at the bacterial support surface interface – appears to enhance the support surface/contaminant interaction

MICROBE / NUTRIENT SCREENING TESTS

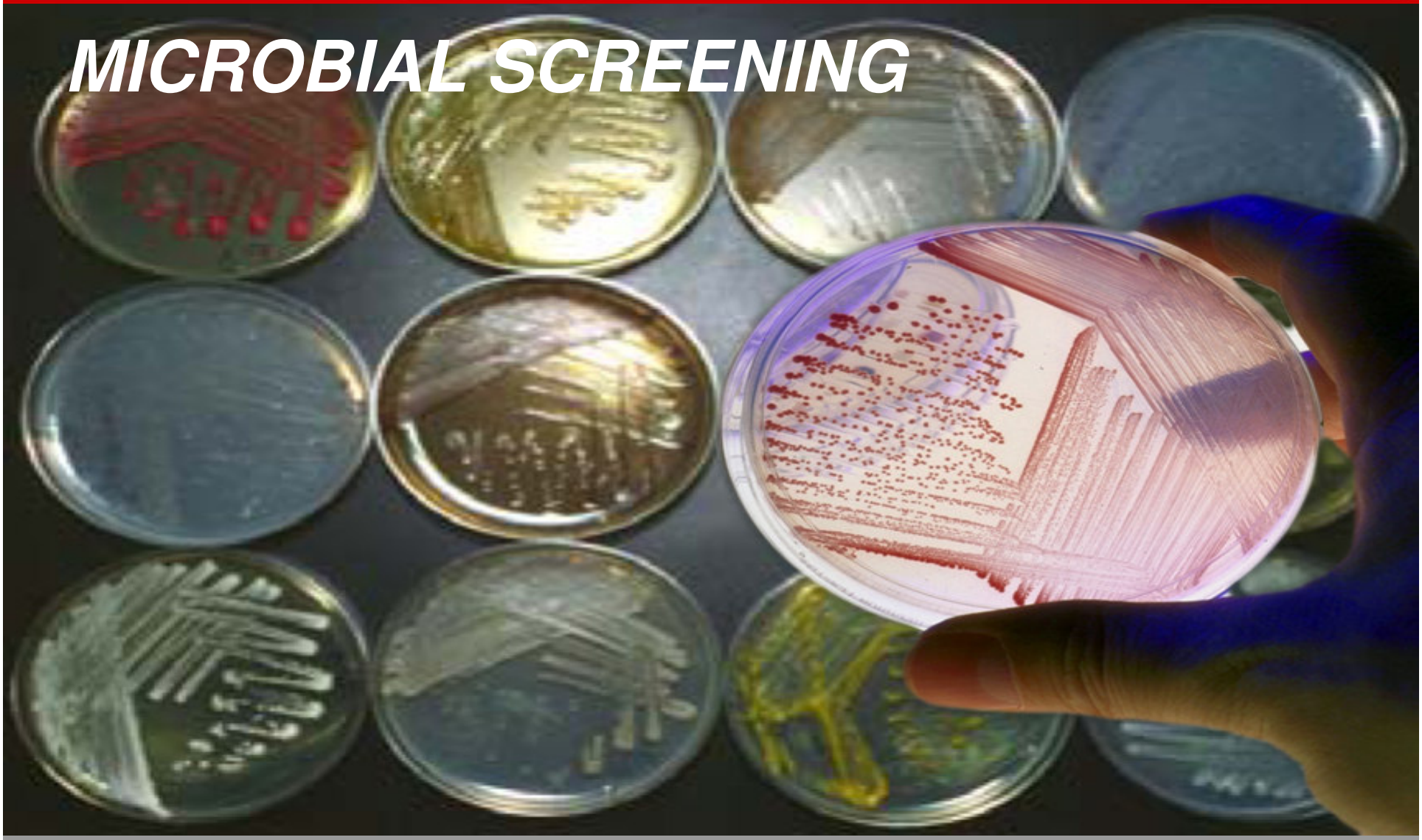
- Not all indigenous microbes perform the contaminant transformations or removals desired
- Select best indigenous and augmented and test as a microbial population in site solutions for highest contaminant transformation and population robustness
- Microbes and nutrients were screened at ~23° C and pH ~7 to select initial microbe populations and appropriate nutrients for EBR batch testing for arsenic, selenium, mercury, and nitrate removal
- Microbes were from the Center repository and various site isolates

THE UNIVERSITY OF UTAH™

TOGETHER WE REACH

DEPARTMENT OF METALLURGICAL ENGINEERING

MICROBIAL SCREENING



EXAMPLE MICROBE / NUTRIENT SCREENING

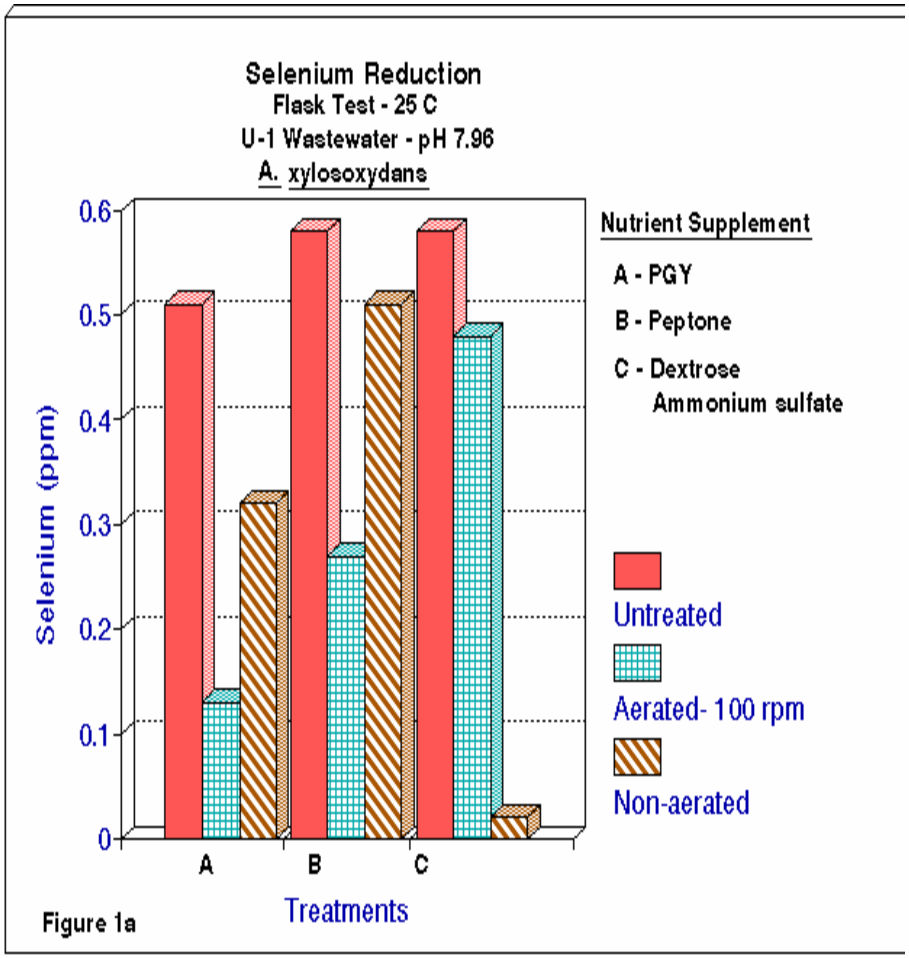


Figure 1a

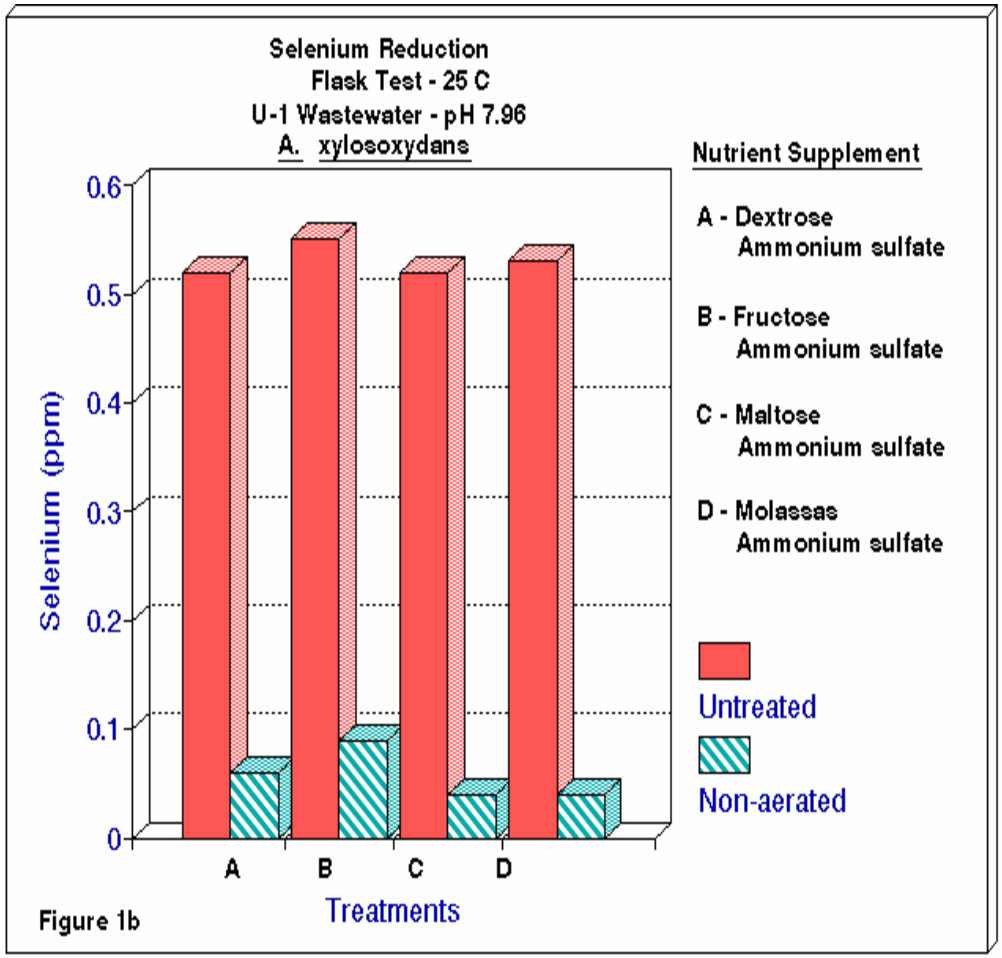
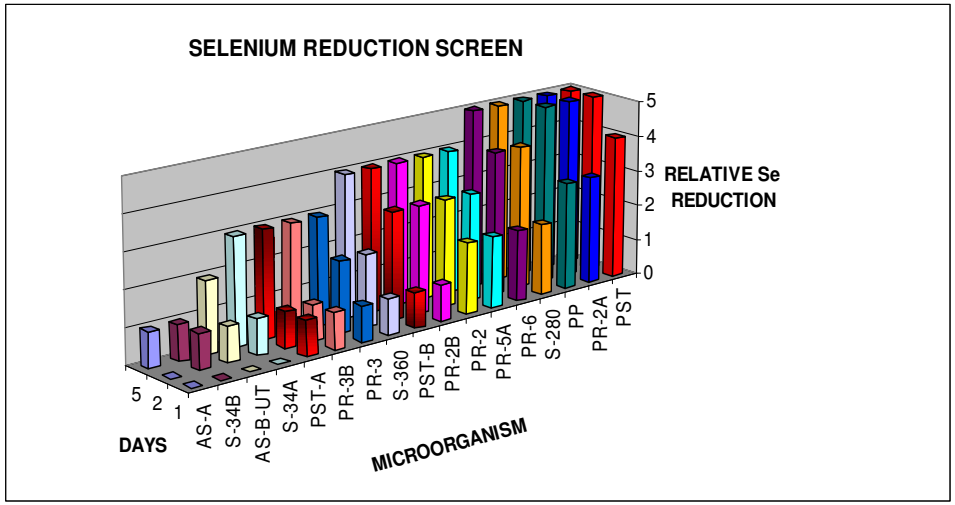
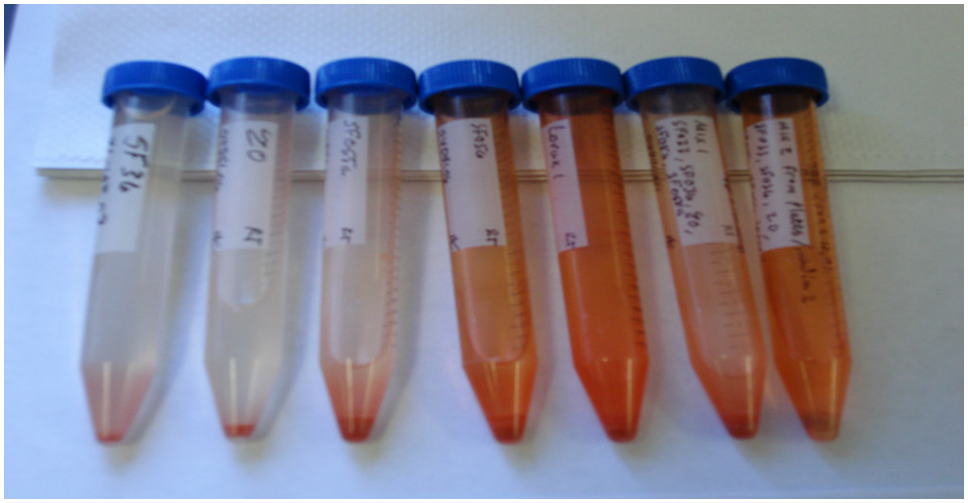


Figure 1b

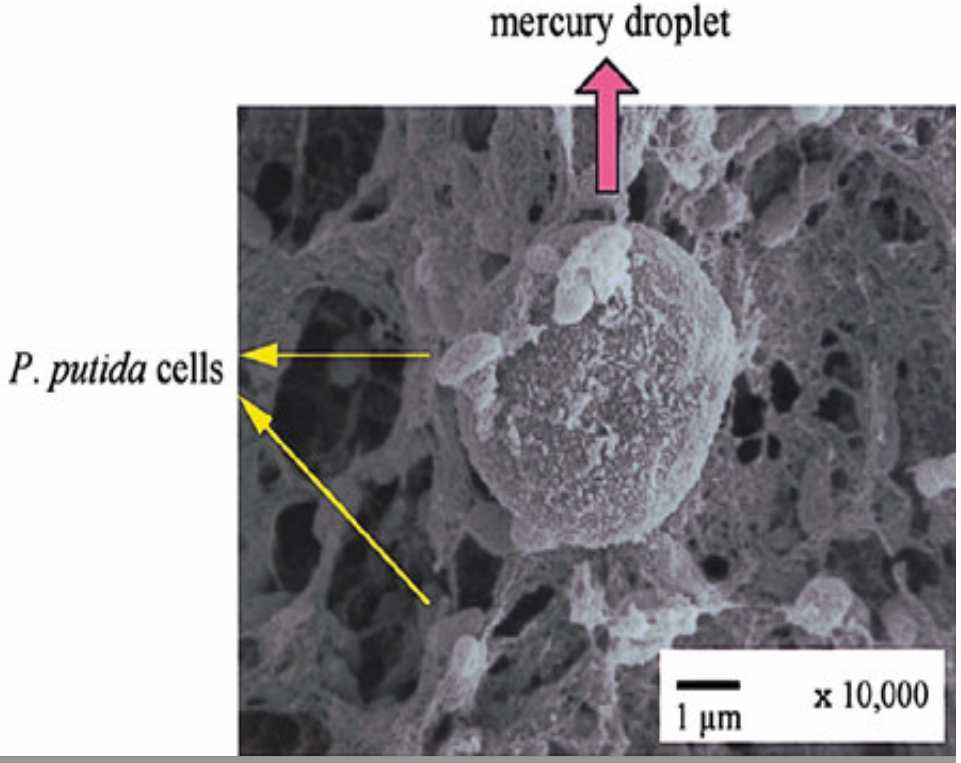
EXAMPLE MICROBE/NUTRIENT SCREENING





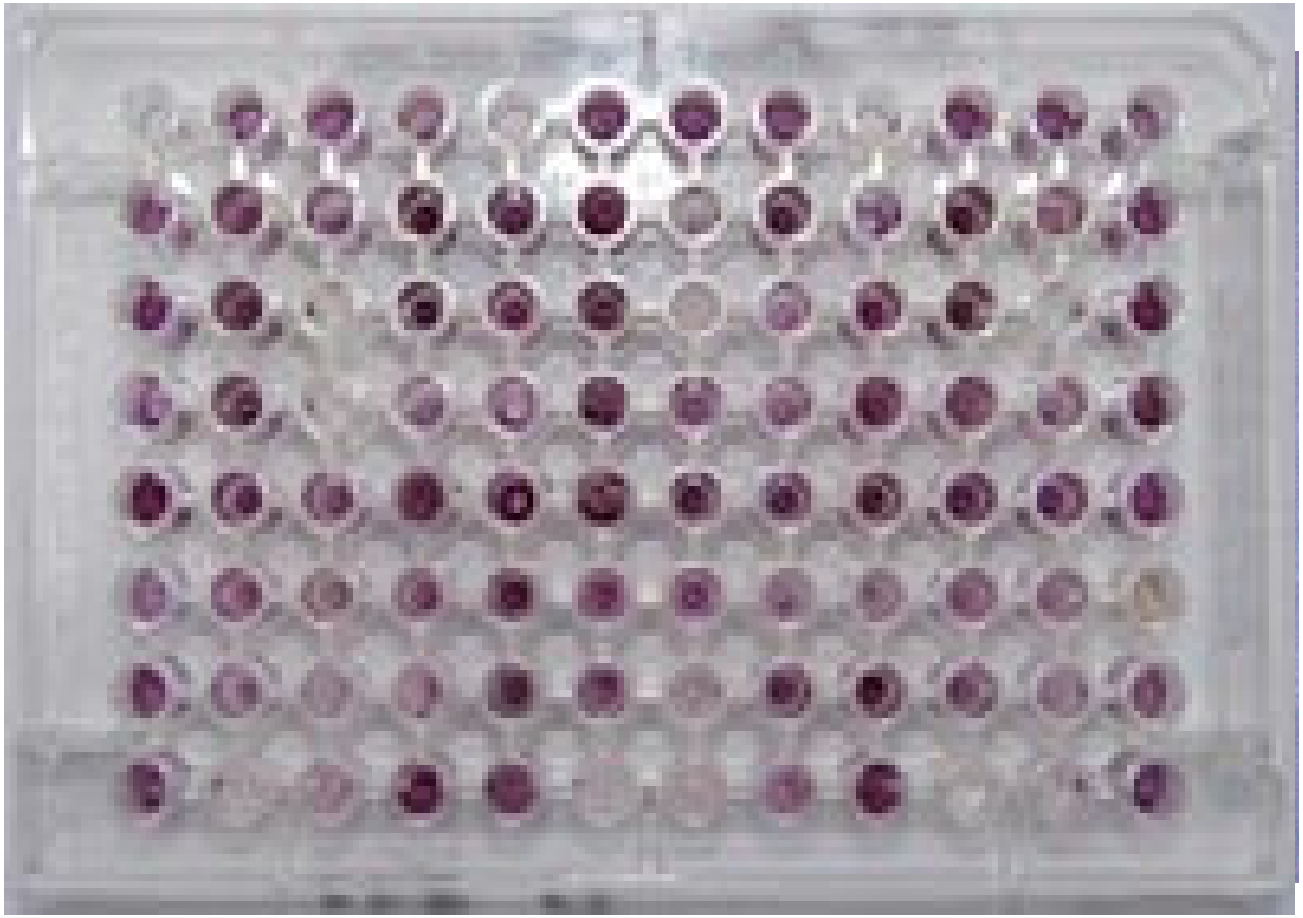
SELENIUM REDUCTION

Pseudomonas sp.
Sulfate Reducing Bacteria

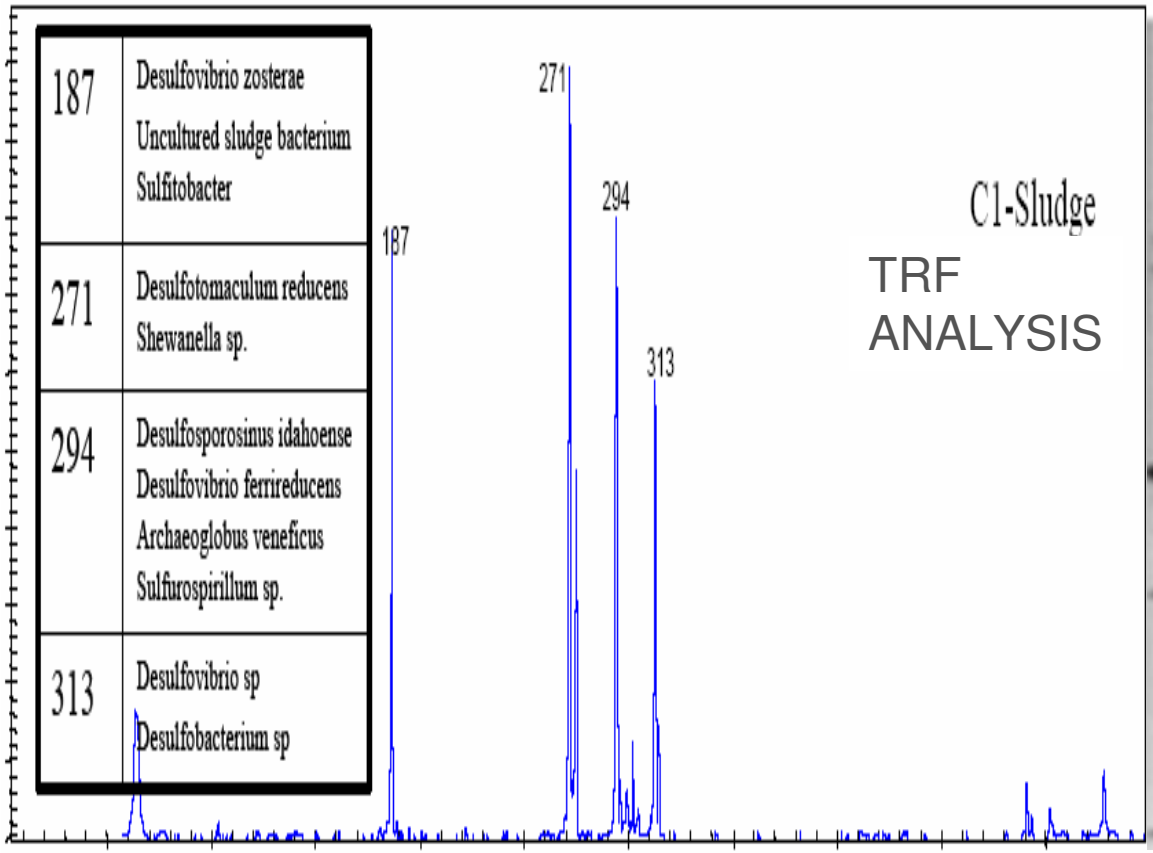


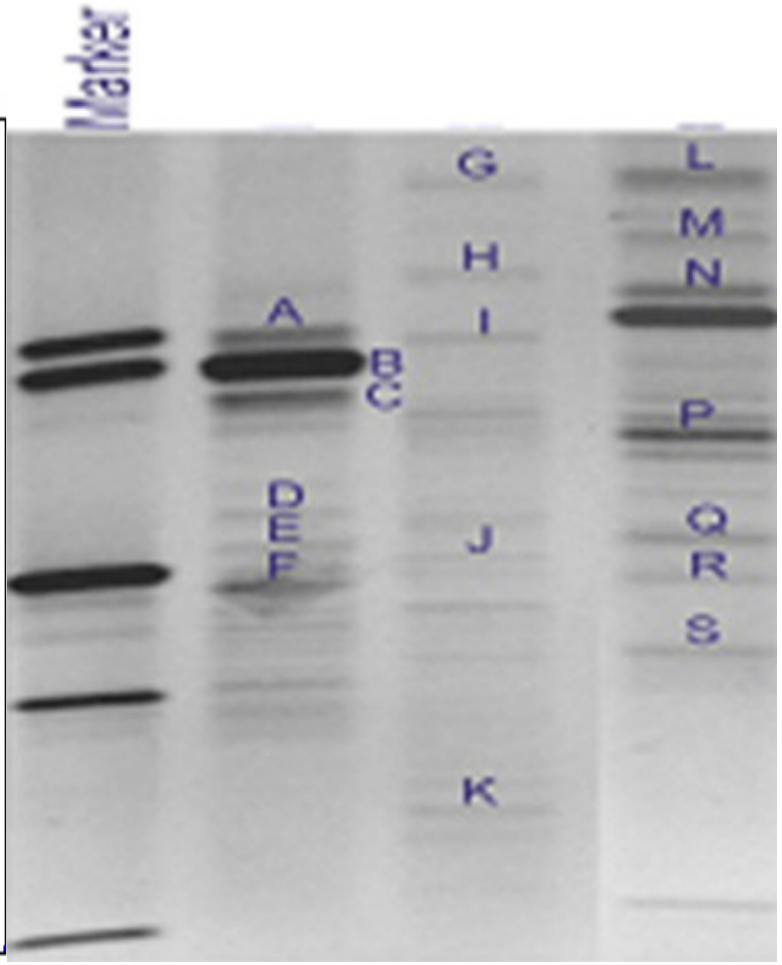
METABOLIC TESTING

- BIOLOG™ plates are used to profile microbial metabolic actions



BACTERIAL POPULATION

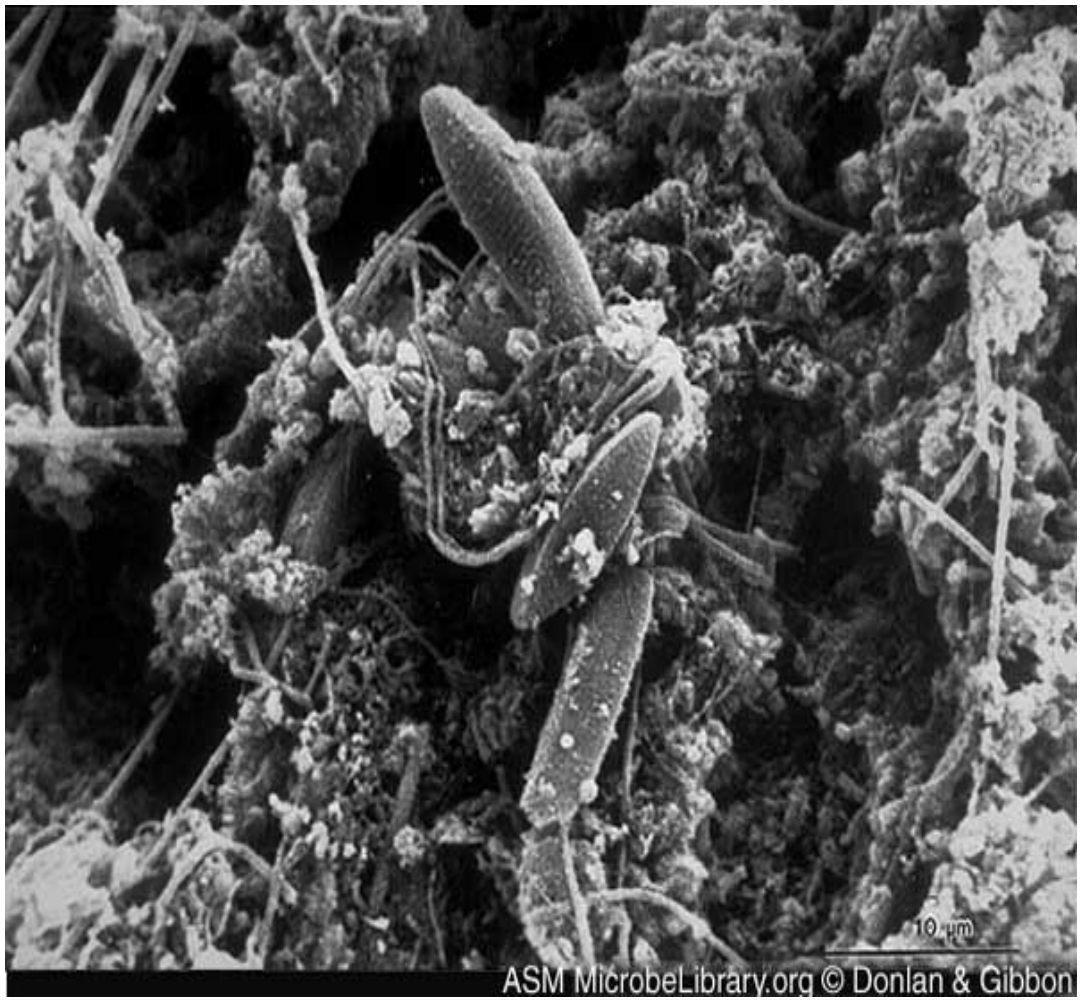




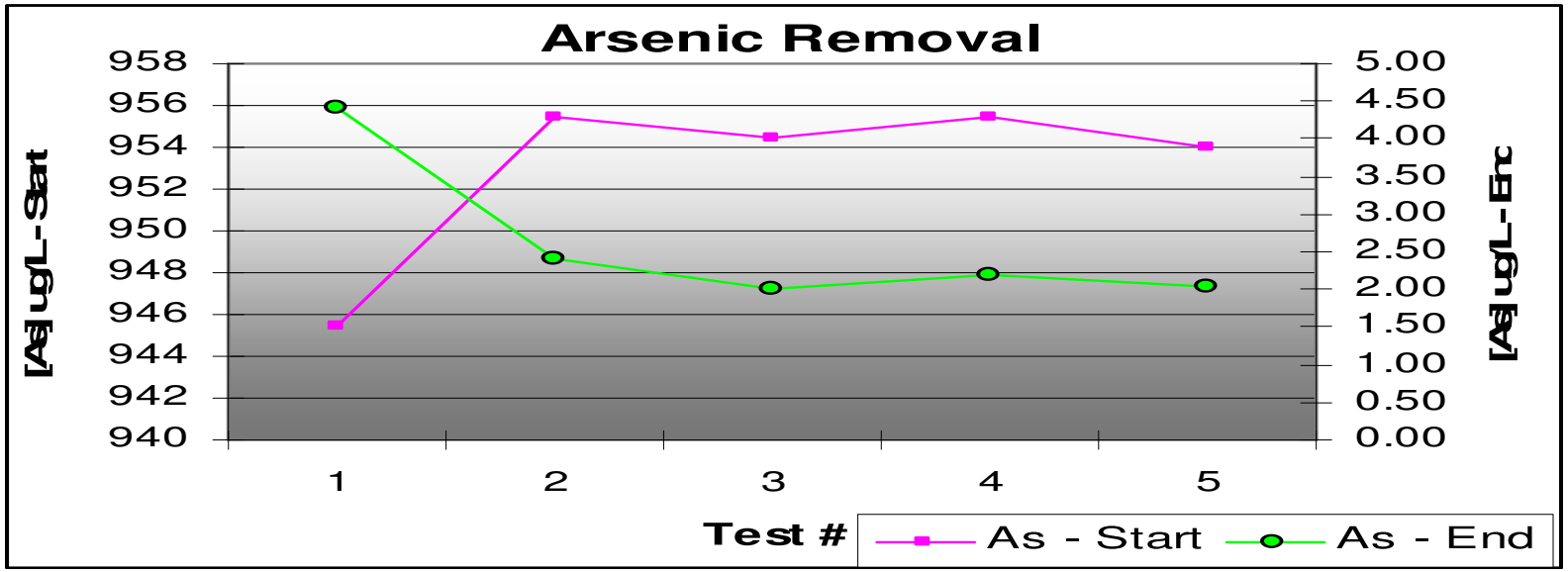
DNA ANALYSIS

BIOFILM POPULATIONS

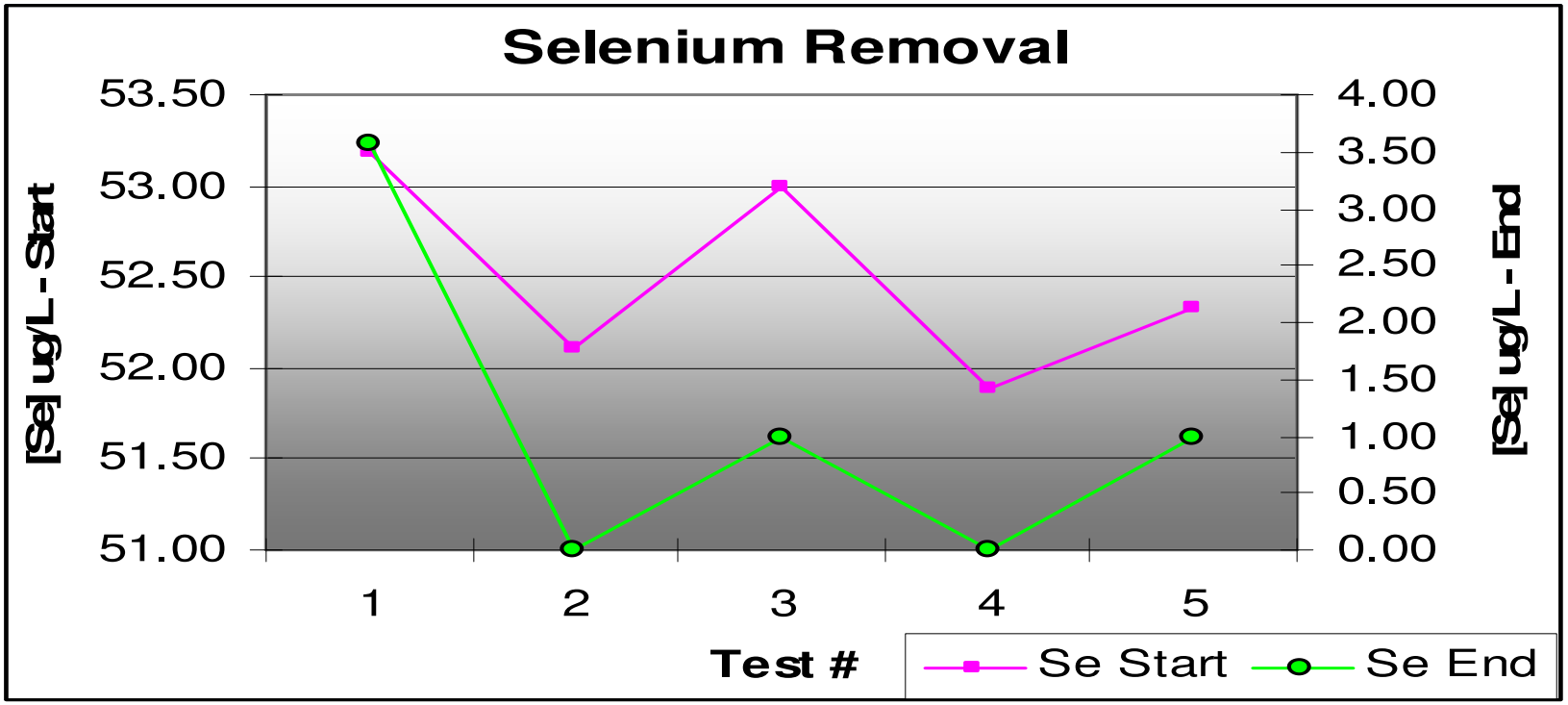
- Selected indigenous and augmented microbes are combined into biofilm populations with the appropriate nutrient components to obtain high contaminant transformation kinetics



ARSENIC SCREENING TESTS

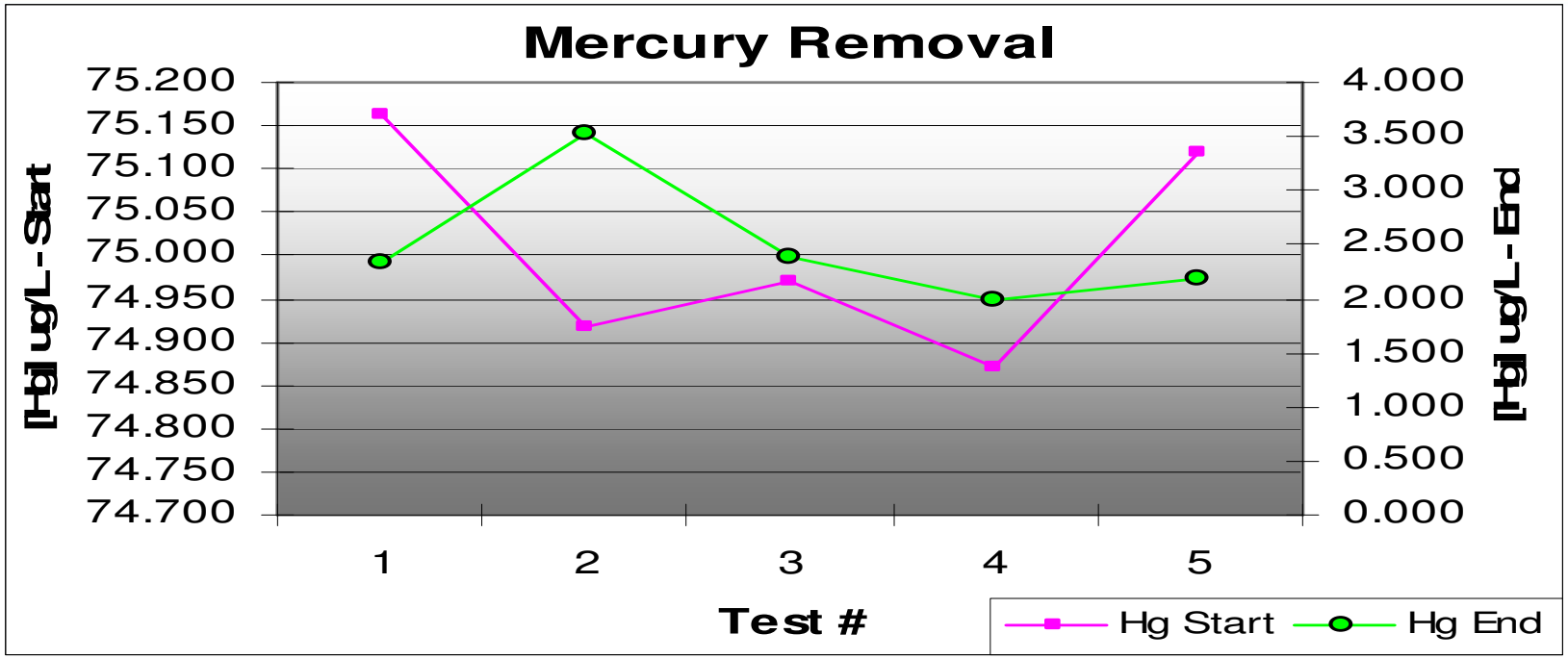


- Tests completed in EBR operated in batch mode using an 18 hr retention time
- Voltage was adjusted from 0.05 to 3V in batch tests – 2 to 3 V produced best As removal
- Tests were conducted using synthetic mine waters at pH ~7 and ~23° C
- Microbes and nutrients were adjusted between tests to obtain optimal As removal



- Tests completed in EBR operated in batch mode using 18 hr retention time
- Voltage was adjusted from 0.05 to 3V in batch tests – 2 to 3 V produced best Se removal
- Tests were conducted using synthetic mine waters at pH ~7 and ~23° C
- Microbes and nutrients were adjusted between tests to obtain optimal Se removal

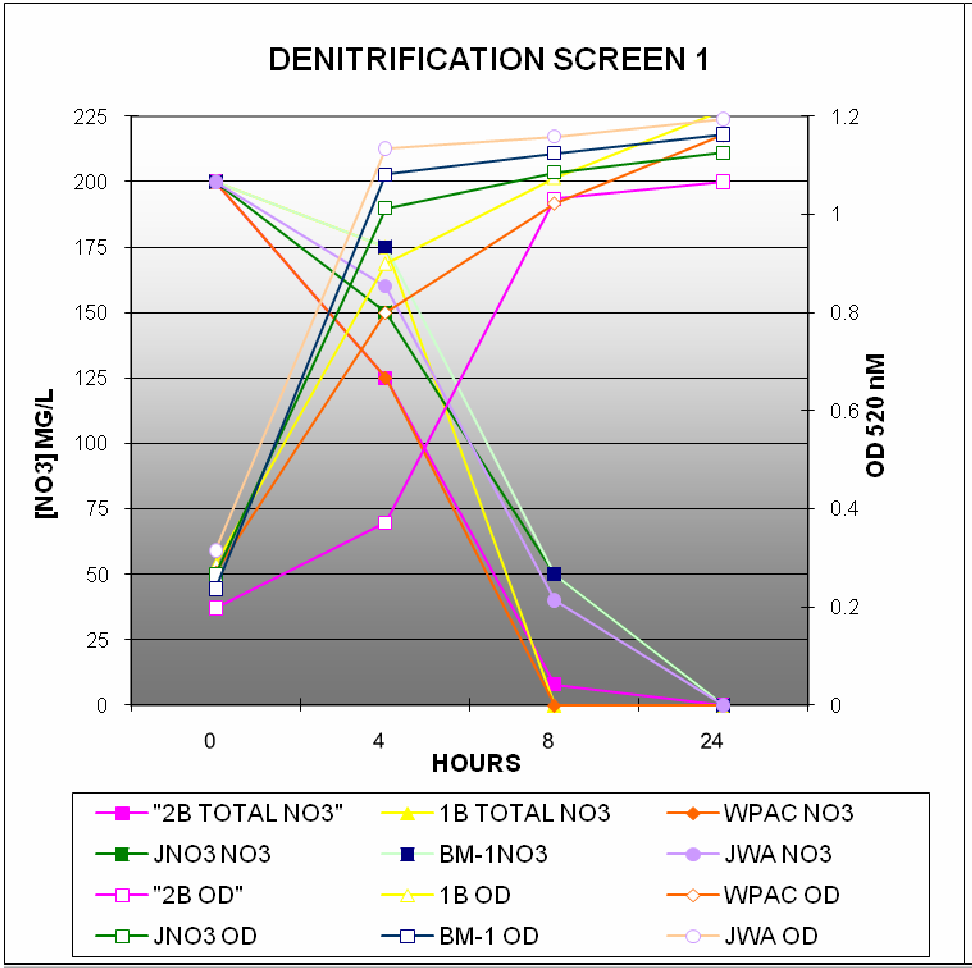
BATCH TESTING – METAL REMOVAL

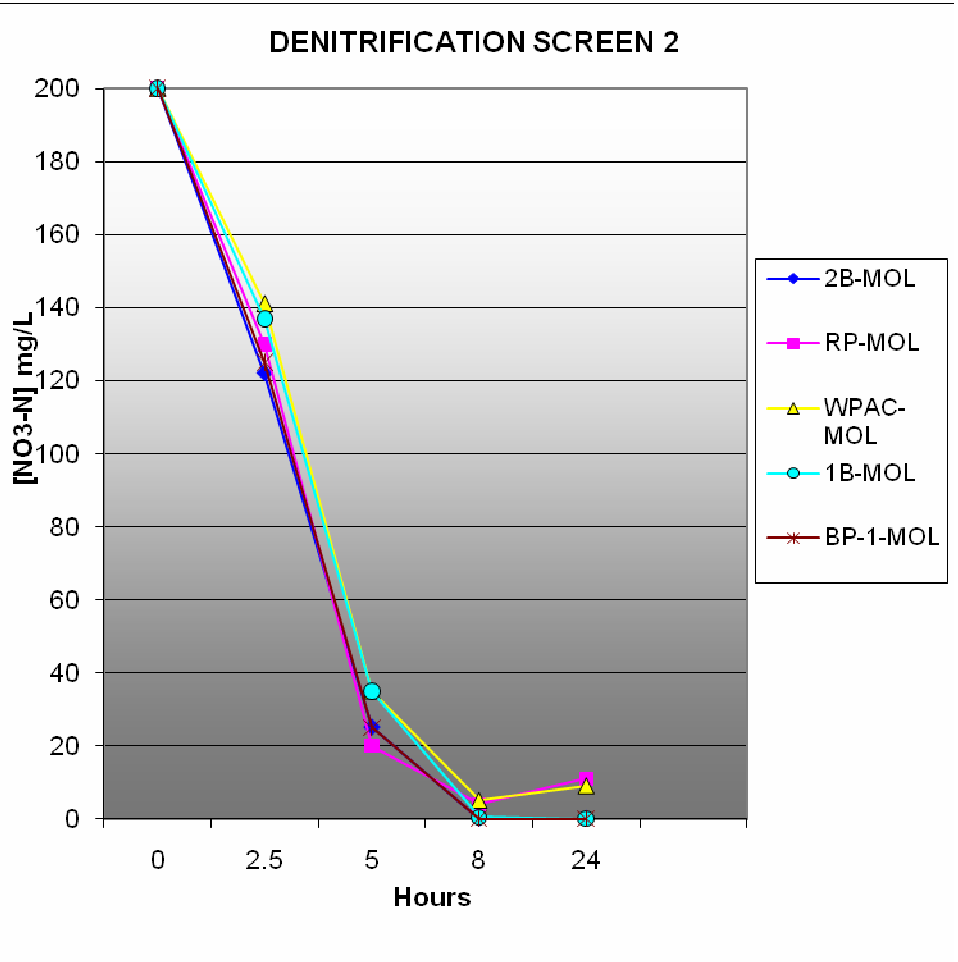


- Tests completed in EBR operated in batch mode using 18 hr retention time
- Voltage was adjusted from 0.05 to 3V in batch tests – 1 to 3 V produced best Hg removal
- Tests were conducted using synthetic mine waters at pH ~7 and ~23° C
- Microbes and nutrients were adjusted between tests to obtain optimal Hg removal

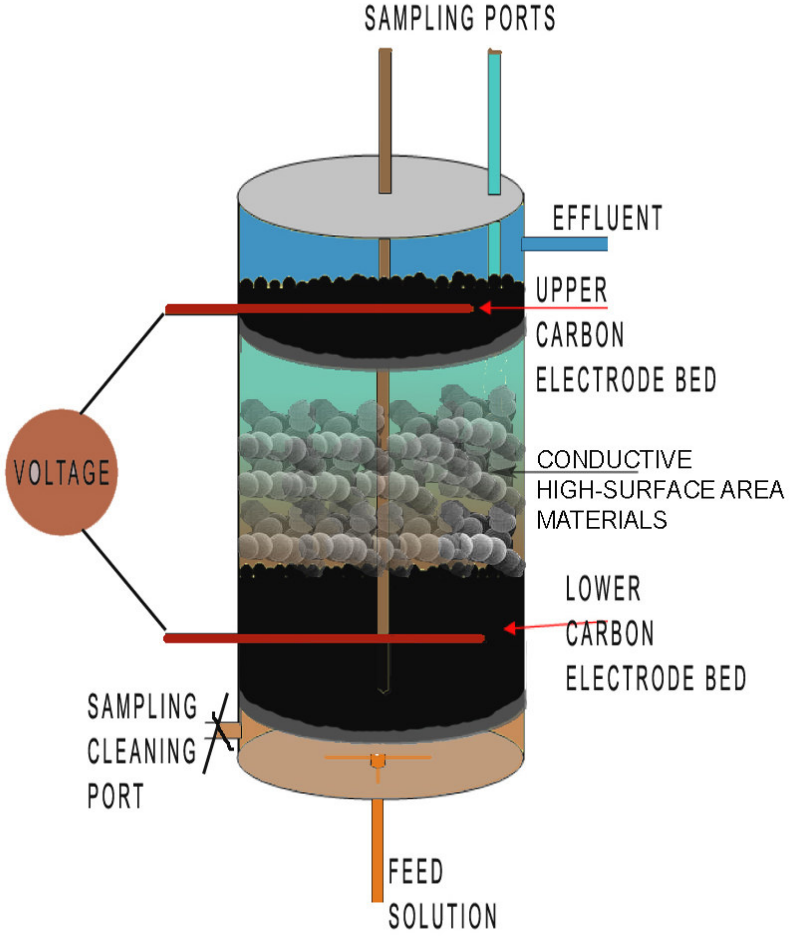
BATCH TESTING – METAL REMOVAL

DENITRIFICATION SCREENING





EBR DYNAMIC TESTS



Sampling ports were used to estimate contaminant removal kinetics

EBR's tests were conducted at ~23° C

All tests were conducted using an ~24 hr retention time per reactor

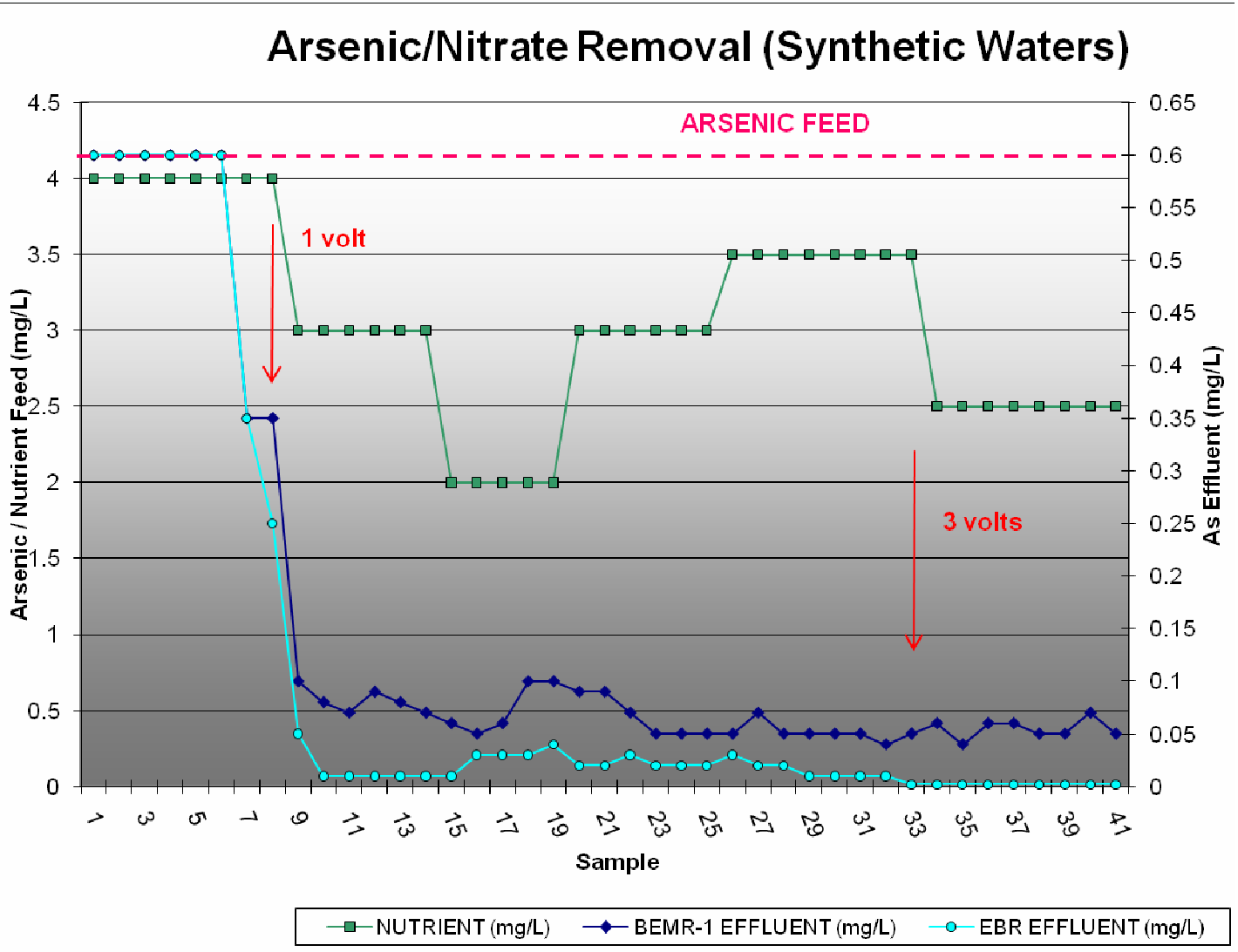
Reactors operated in up-flow, and approximate plug-flow conditions

BEMR – (2) EBR's in series without applied voltage

Both BEMR's received nutrients

Synthetic mine waters were used In both reactors

A single EBR was used with applied voltage as indicated –
½ the retention time
½ the nutrients



200 mg/L NITRATES REMOVED IN <6 HR

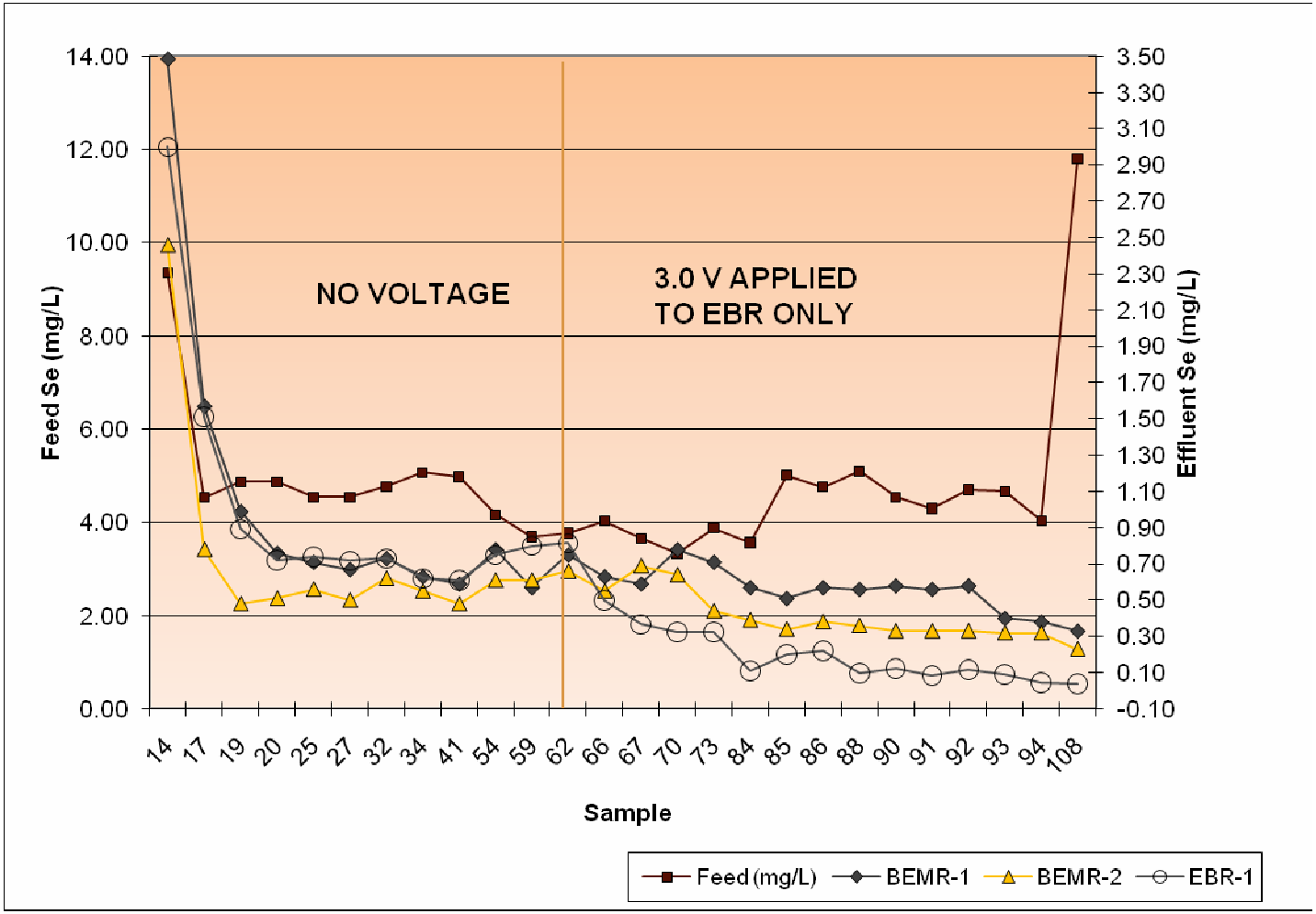
SELENIUM REMOVAL – PROCESS WATERS

BEMR – (2) EBR's in series without applied voltage

Both BEMR's received nutrients

Process waters were used in both reactors

A single EBR was used with applied voltage as indicated –
~½ the retention time
~½ the nutrients



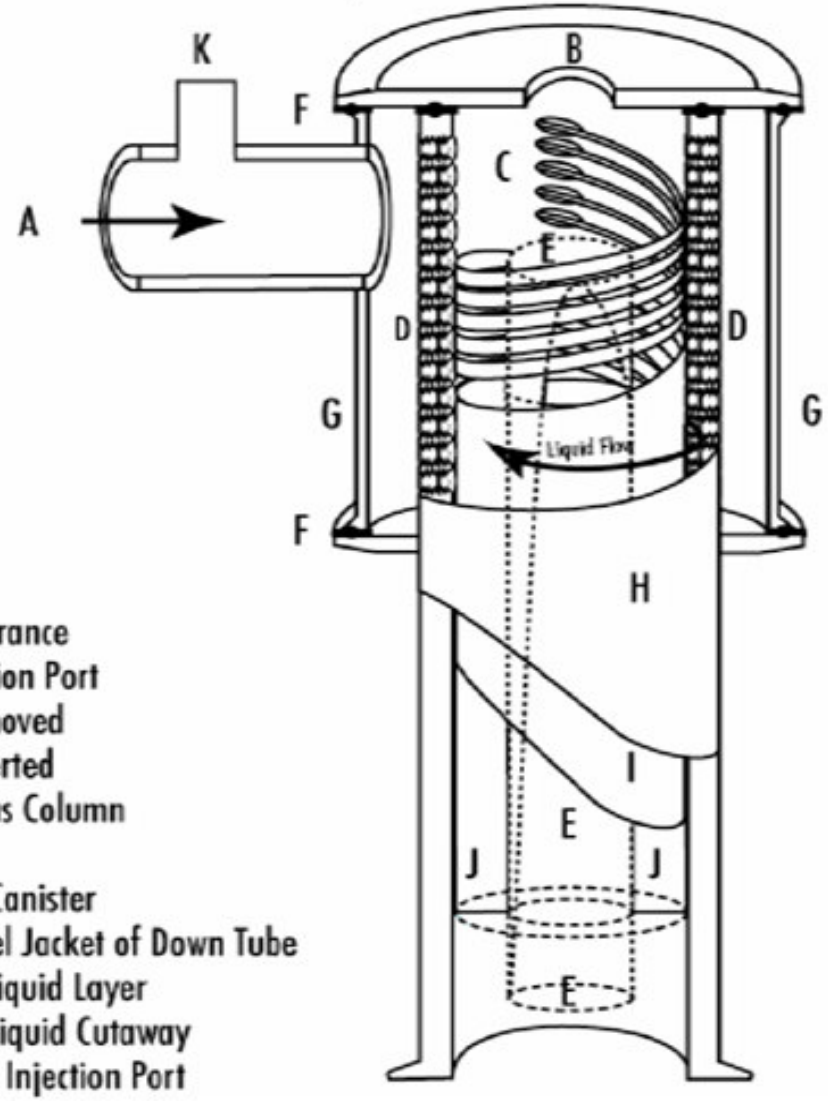
OTHER METAL REMOVAL
(ARESNIC BIOREACTORS)

ITEM	ELEMENT	Al	S	Fe	Ni	Cu	Zn	Mo	Ag	Cd	Sb
		mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
AVERAGE FEED WATERS		998.95	460.67	32	6.23	3	19.48	632.52	2.04	1.77	14.93
AVERAGE EBR EFFLUENT		23.21	76.09	139.41	10.41	0.04	21.65	55.65	0	0.18	10.69
(3 months operation)				(FROM ELECTRODE)							

WATER GAS MIXING (WGM) TECHNOLOGY

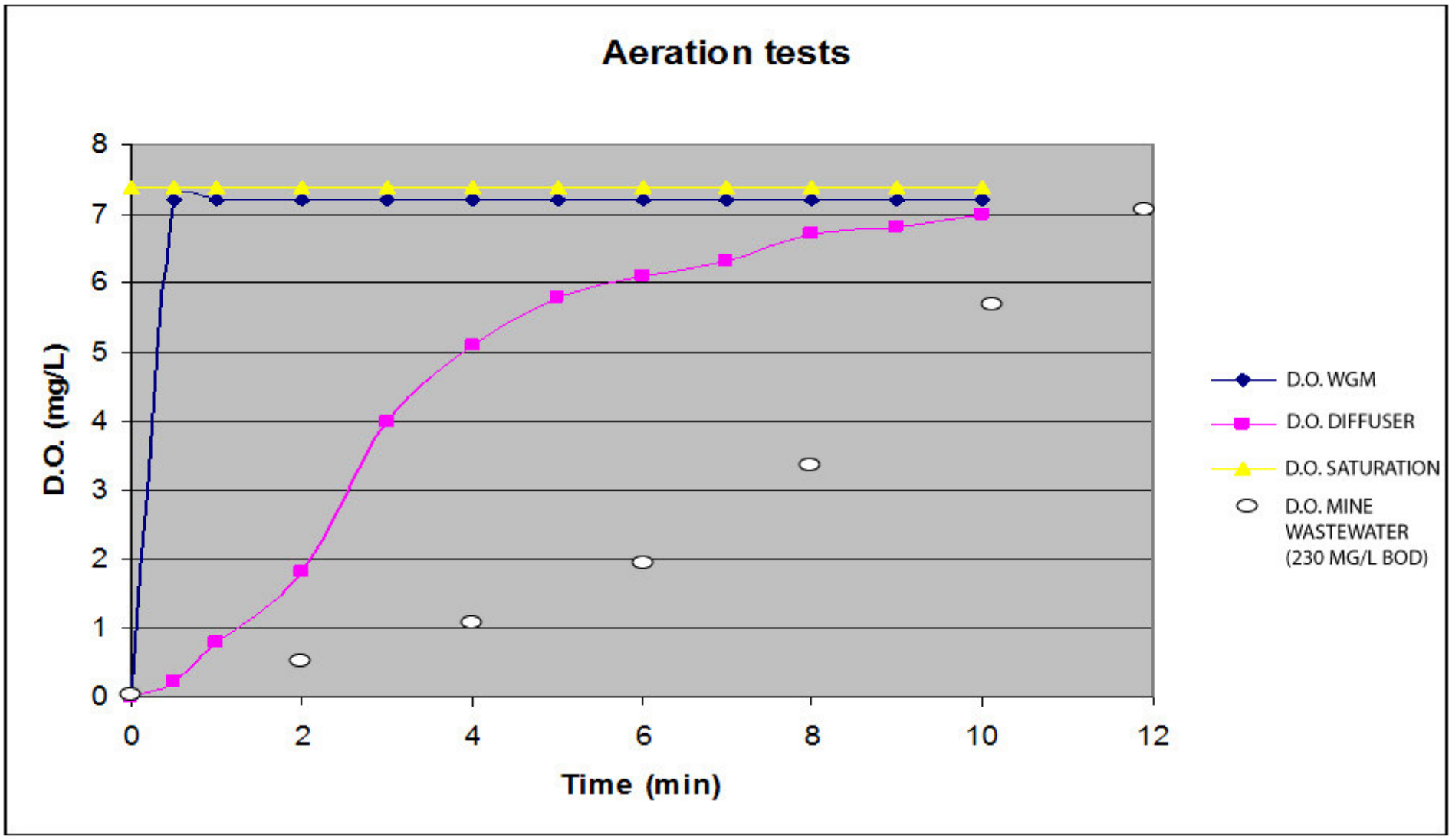
- New patented technology is based on a modification of the air-sparged hydrocyclone that rapidly oxygenates water in a thin film
  - Uses compressed air
  - In laboratory tests waters oxygen was removed using chemical pretreatment
  - In field tests oxygen was not present and BOD levels were at ~230 mg/L
- In the laboratory, oxygen saturation was achieved in seconds
- In the field with ~230 mg/L BOD, oxygen saturation was achieved in minutes

WATER GAS MIXING HEAD



A - Liquid Entrance
B - Gas Injection Port
C - Plugs Removed
D - Plugs Inserted
E - Central Gas Column
F - Gasket
G - Pressure Canister
H - Outer Steel Jacket of Down Tube
I - Spinning Liquid Layer
J - Spinning Liquid Cutaway
K - Chemistry Injection Port

WGM
(WATER GAS MIXER)
AEROBIC BIOTREATMENT
BOD REDUCTION / AERATION


Aeration tests
D.O. (mg/L)
0
1
2
3
4
5
6
7
8
0
2
4
6
8
10
12
Time (min)
D.O. WGM
D.O. DIFFUSER
D.O. SATURATION
D.O. MINE WASTEWATER (230 MG/L BOD)

SUMMARY

- The EBR's performance in bench-scale tests had significantly better performance and potential cost savings over conventional bioreactors for arsenic and nitrate and selenium removal
  - Greater than two times the contaminant removal kinetics were observed
  - EBR nutrient utilization was approximately ½ the conventional bioreactor
  - Lower contaminant effluents were consistently observed
    - ~4 months for the arsenic/nitrate EBR's
    - ~7 months for the selenium EBR

SUMMARY

- EBR nutrient costs estimated at ~$0.10 to $0.25 per 1,000 gallons treated
- EBR capital costs estimated at ~1/2 to ~1/3 that of conventional bioreactors
- WGM Technology aeration costs ~1/10 that of conventional blowers and diffusers
- Odor in BOD waters eliminated as oxygen levels approached saturation (minutes)

RESEARCH SPONSORS

CENTERS·OF EXCELLENCE

Utah!
Where ideas connect

WORLD WATER

BARRICK

LORAX ENVIRONMENTAL

CONTACT

D. Jack Adams, Ph.D.
University of Utah
Dept. Metallurgical Engineering
jack.adams@utah.edu
(801) 712-2760