Perchlorate Degradation in Fixed Bed Bioreactors -2

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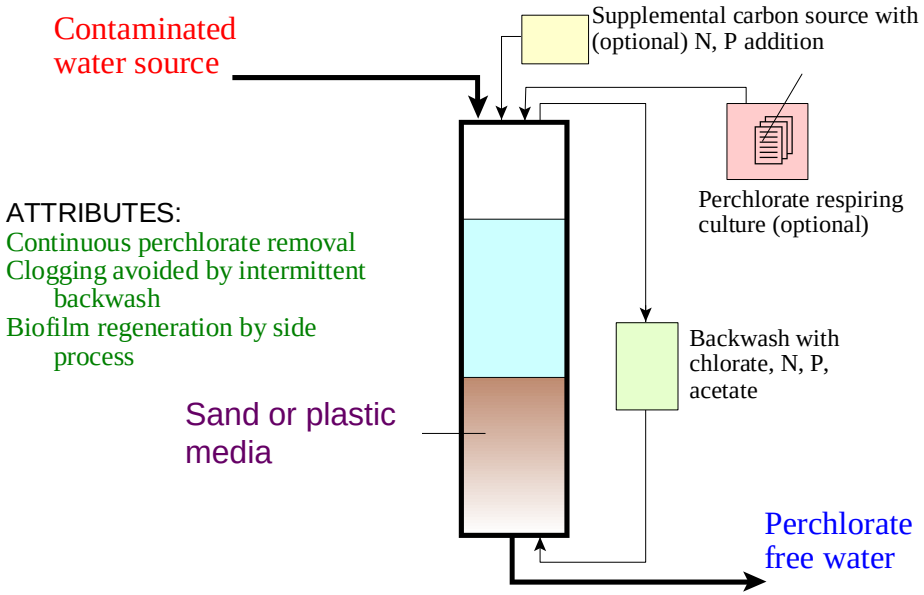
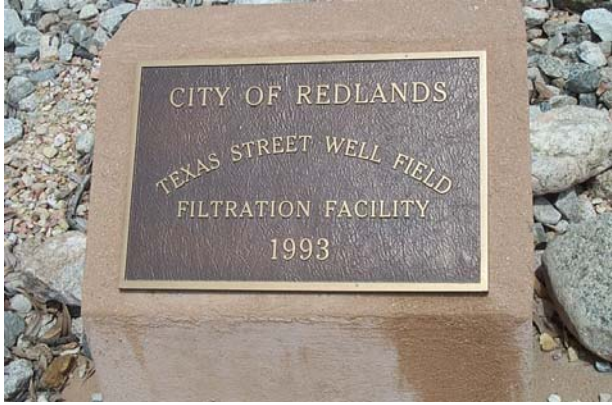
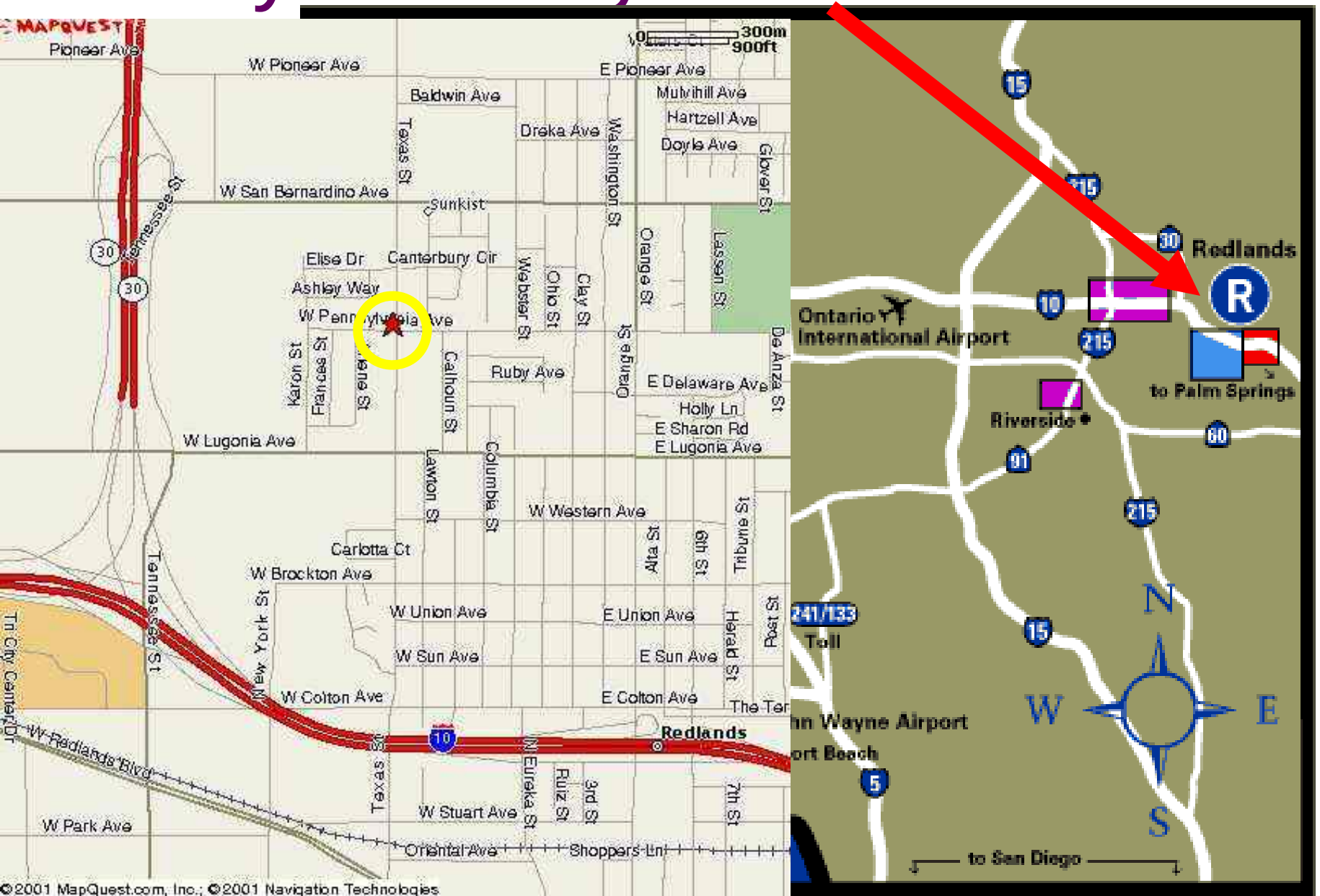


AWWARF Project
Phase 2
FIELD TESTS



- Phase 1 research had 3 successful tests
  - Fixed bed bioreactor (acetate feed)
  - Gas phase, autotrophic bioreactor (hydrogen gas)
  - Membrane bioreactor (lactate or acetate)
- For phase 2, we could only select one process→ Acetate-fed, fixed bed bioreactor
  - Low cost, more commonly available technologies
- Camp, Dresser & McKee was subcontracted for construction of the pilot scale reactor
- City of Redlands provided their site: structure for the reactor; groundwater

Study site: City of Redlands



columns
(shut down due to perchlorate breakthrough)

Groundwater Characteristics

Parameter	Value	Units
Perchlorate	50 - 120	ug/L
Nitrate	4-4.5	mg/L-N
Oxygen	8–10	mg/L
TCE	3-5	ug/L
1,1-DCE	1-2	ug/L


Bioreactors housed on site in a converted garage (Redlands, CA)

Morning Session Part 2

- 10:30 Overview of pilot scale bioreactor tests: Bruce Logan
- 10:40 Pilot study- Sand medium reactor: Booki Min
- 11:00 Pilot study- Plastic medium reactor: Bruce Logan
- 11:20 Economic analysis: Scale up and commercialization: Patrick Evans (CDM)
- 11:40 In situ bioremediation of perchlorate: Evan Cox, Goesyntec Consultants

- 12:00 LUNCH BREAK

Pilot-scale Tests of Fixed Bed Reactors for Perchlorate Degradation- Sand Medium Bioreactor

Booki Min and Bruce Logan
Department of civil and Environmental Engineering
The Pennsylvania State University

Overview

- The sand medium bioreactor was inoculated with a perchlorate-reducing bacterium, *Dechlorosoma* sp.KJ.
- Groundwater contains oxygen, perchlorate, and nitrate as potential electron acceptors
- Groundwater, Acetic acid (electron donor), and Nutrients (N and P as ammonium phosphate) were added to the reactor
- The reactor was operated at flow rates of 0.063 to 0.126 L/s (1 to 2 gpm) for about 6-months in Redlands, CA

Texas Street Well Site

Raw water supply from well

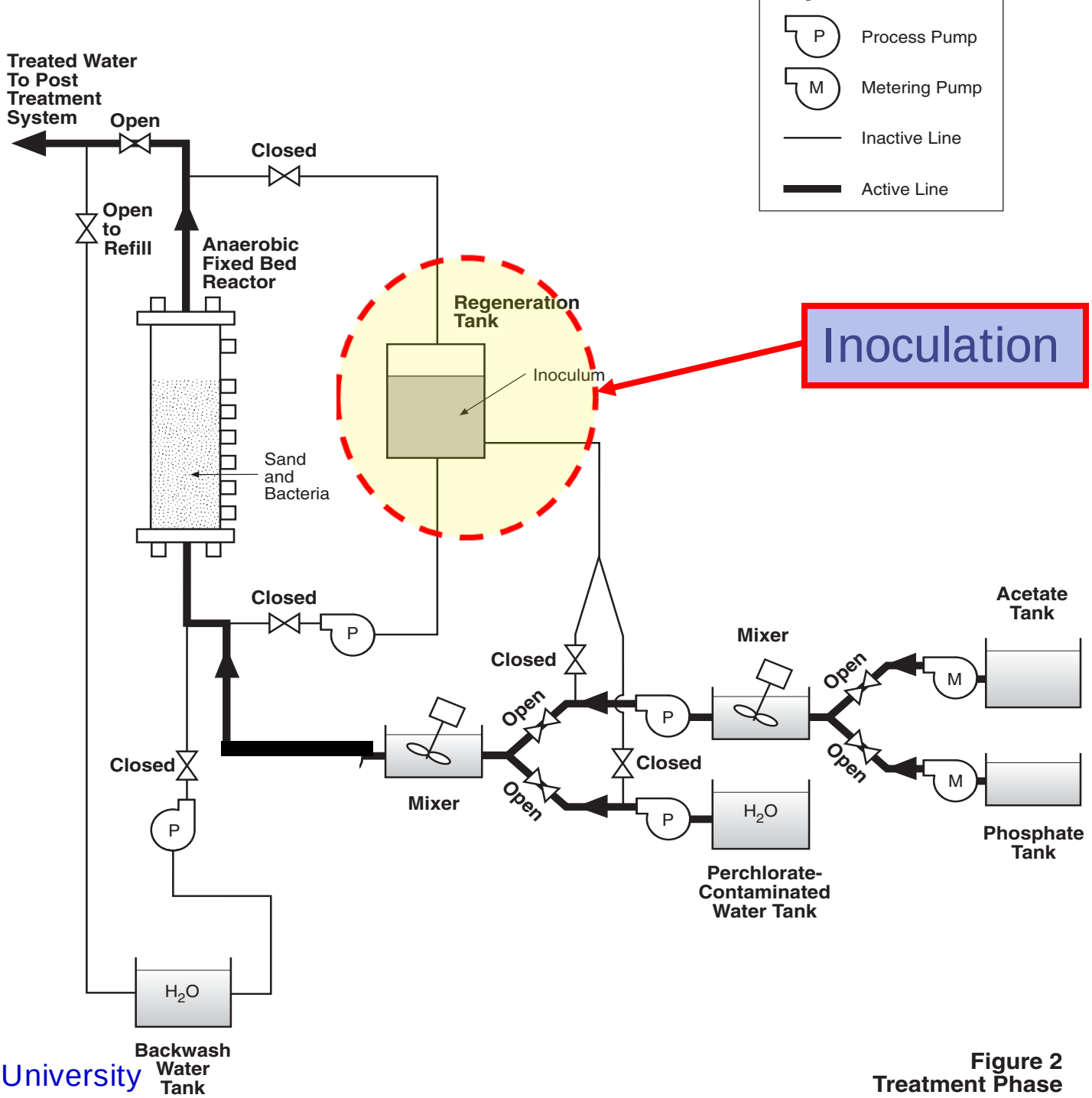


Figure 2
Treatment Phase


Drums used for inoculation
Nitrogen Tank


Perchlorate, Acetate, and Nutrients

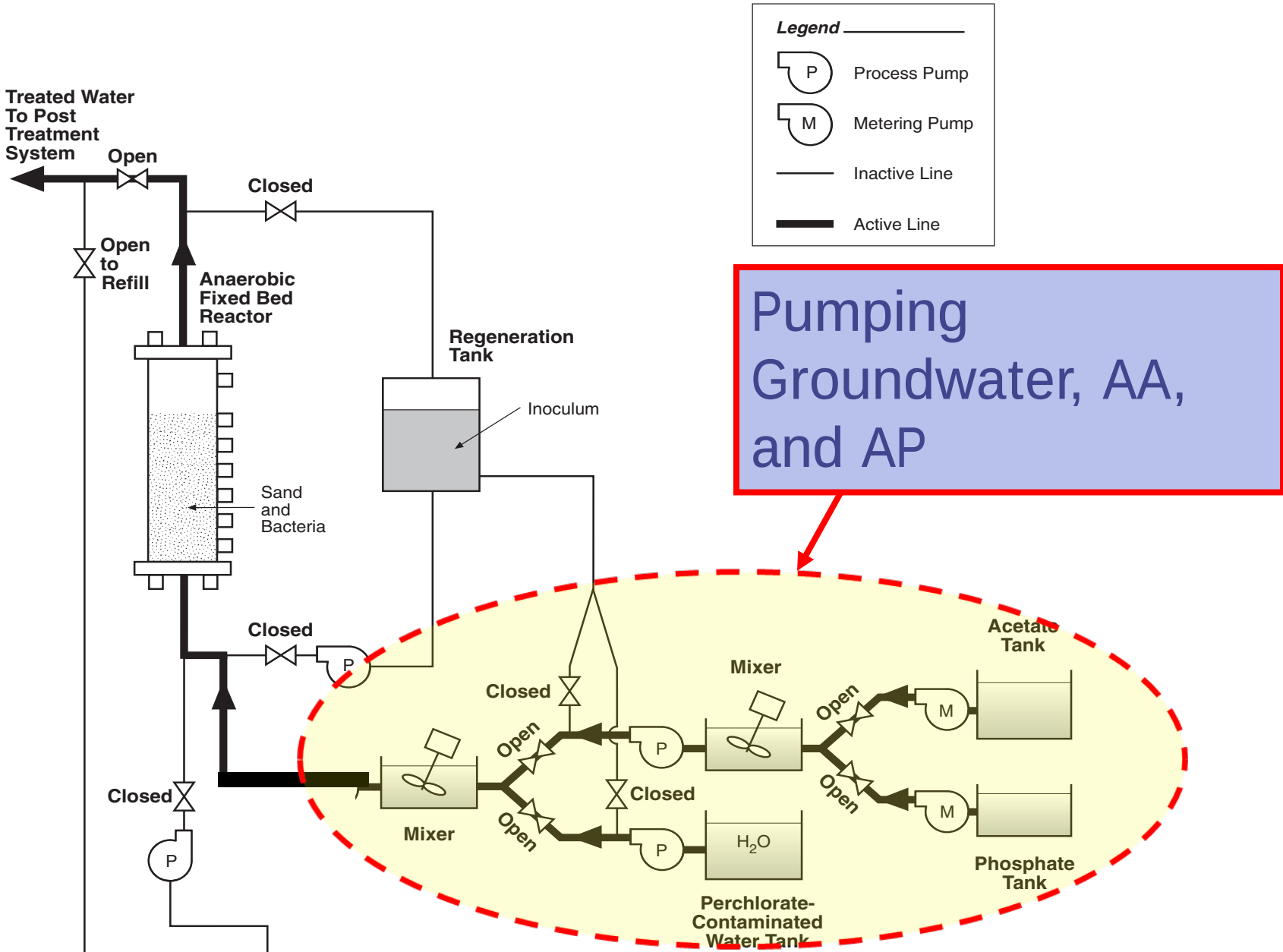
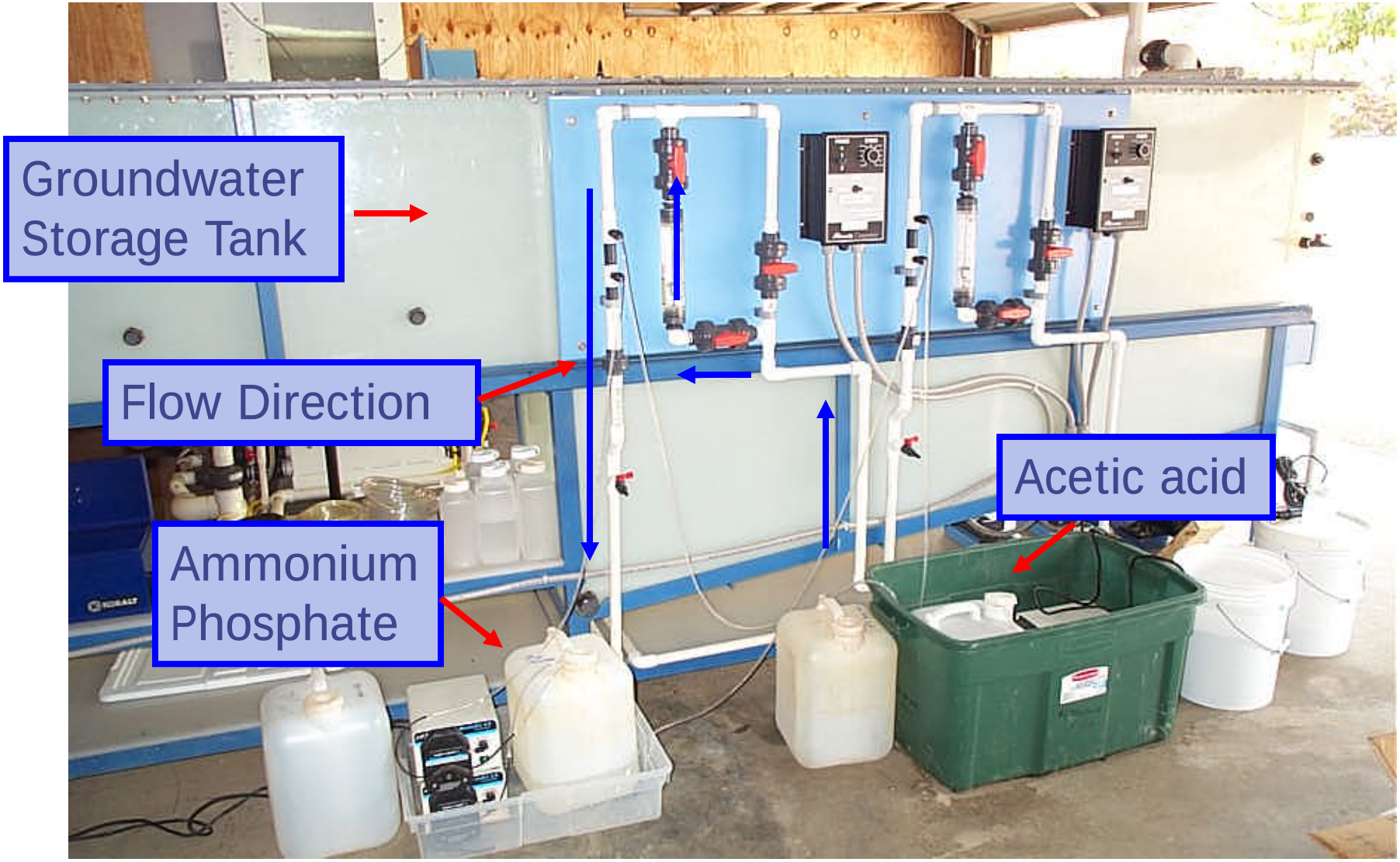
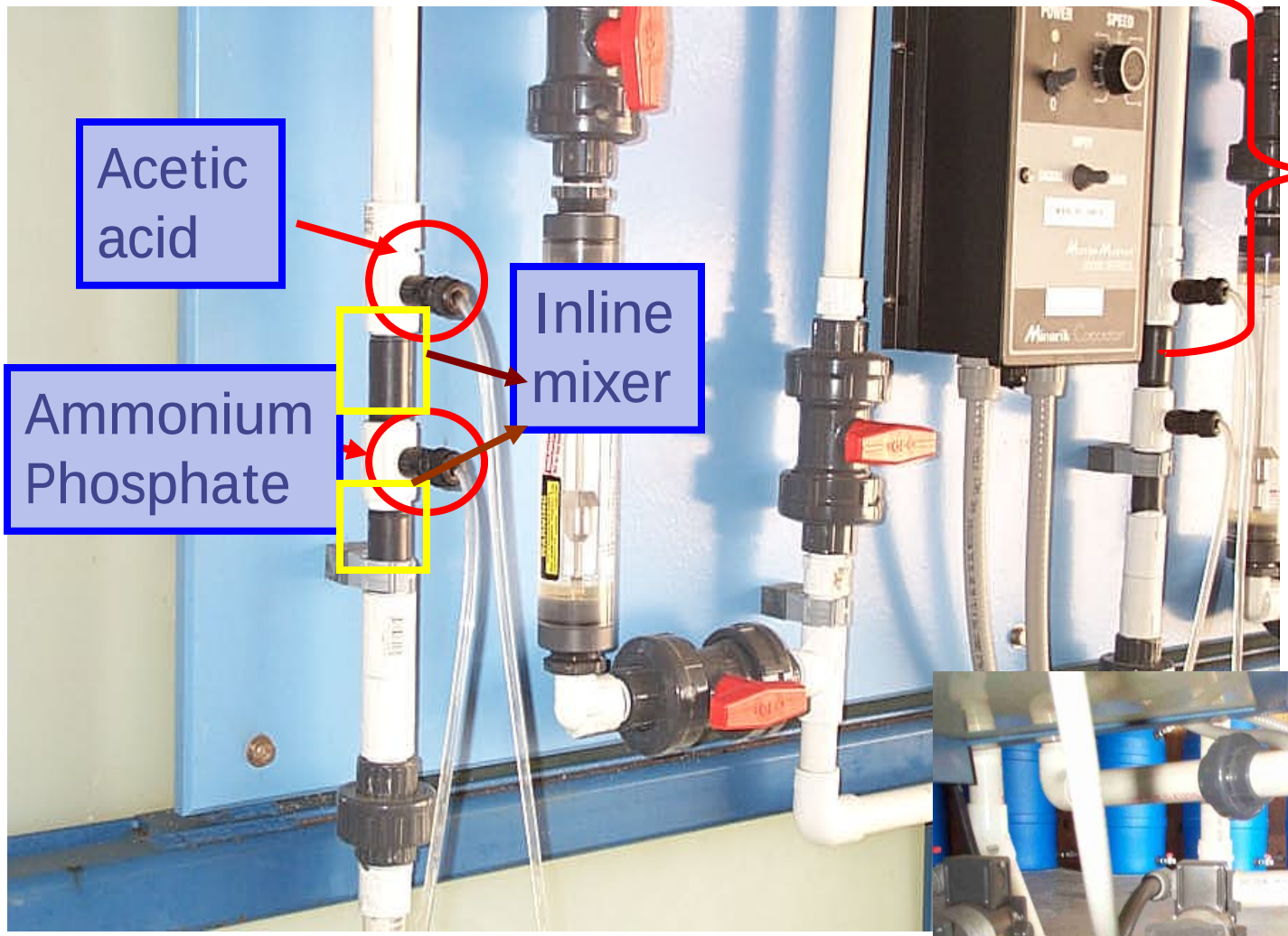

Legend
P
Process Pump
M
Metering Pump
Inactive Line
Active Line
Pumping Groundwater, AA, and AP
Treated Water To Post Treatment System
Open
Closed
Open to Refill
Anaerobic Fixed Bed Reactor
Regeneration Tank
Inoculum
Sand and Bacteria
Closed
P
Closed
Mixer
Open
Open
Closed
P
Mixer
Open
Open
M
Acetate Tank
Closed
P
Open
M
Phosphate Tank
H2O
Perchlorate-Contaminated Water Tank
Closed
P
H2O
Backwash

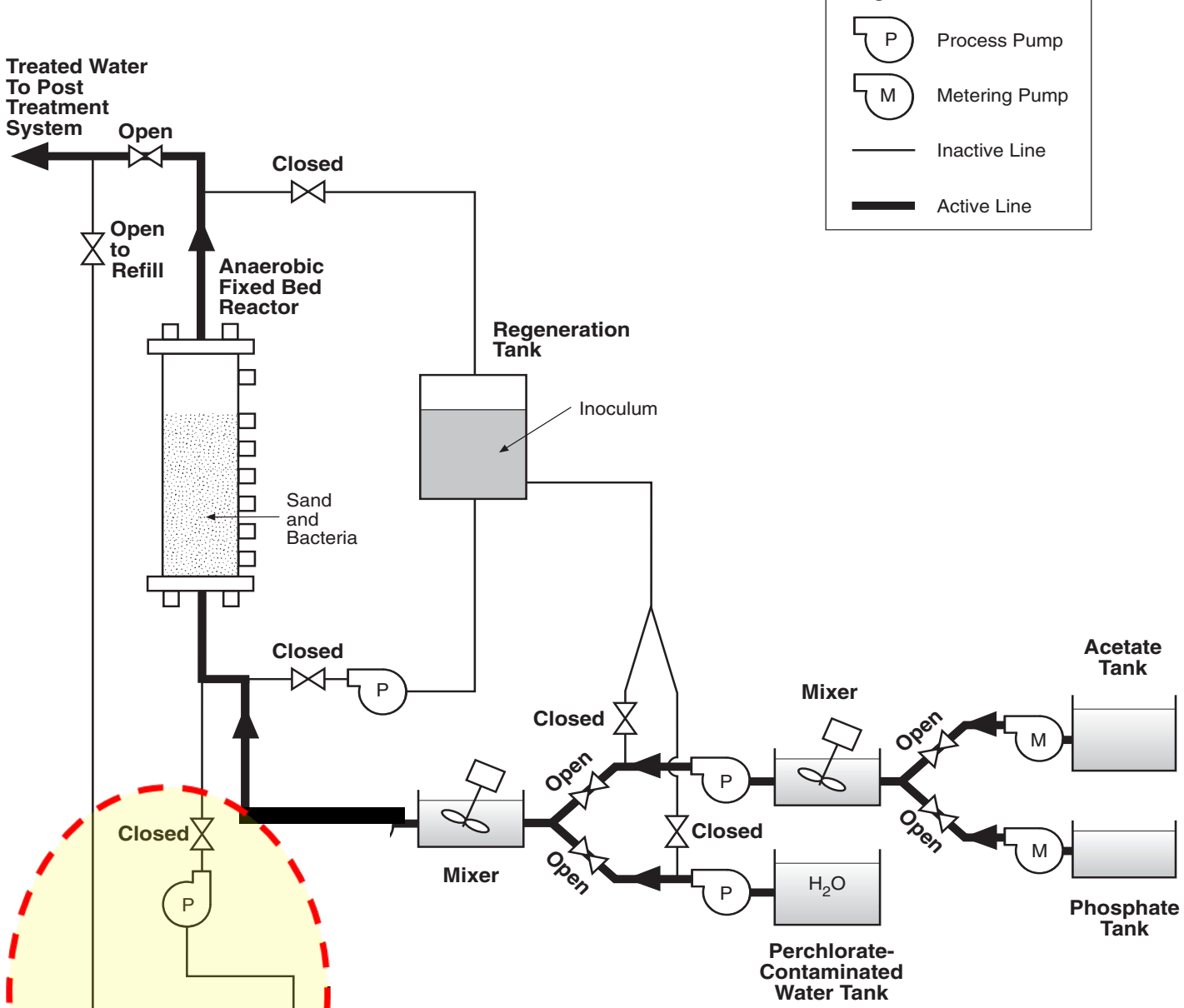
Figure 2

Groundwater, Acetic acid, and Nutrients pumping



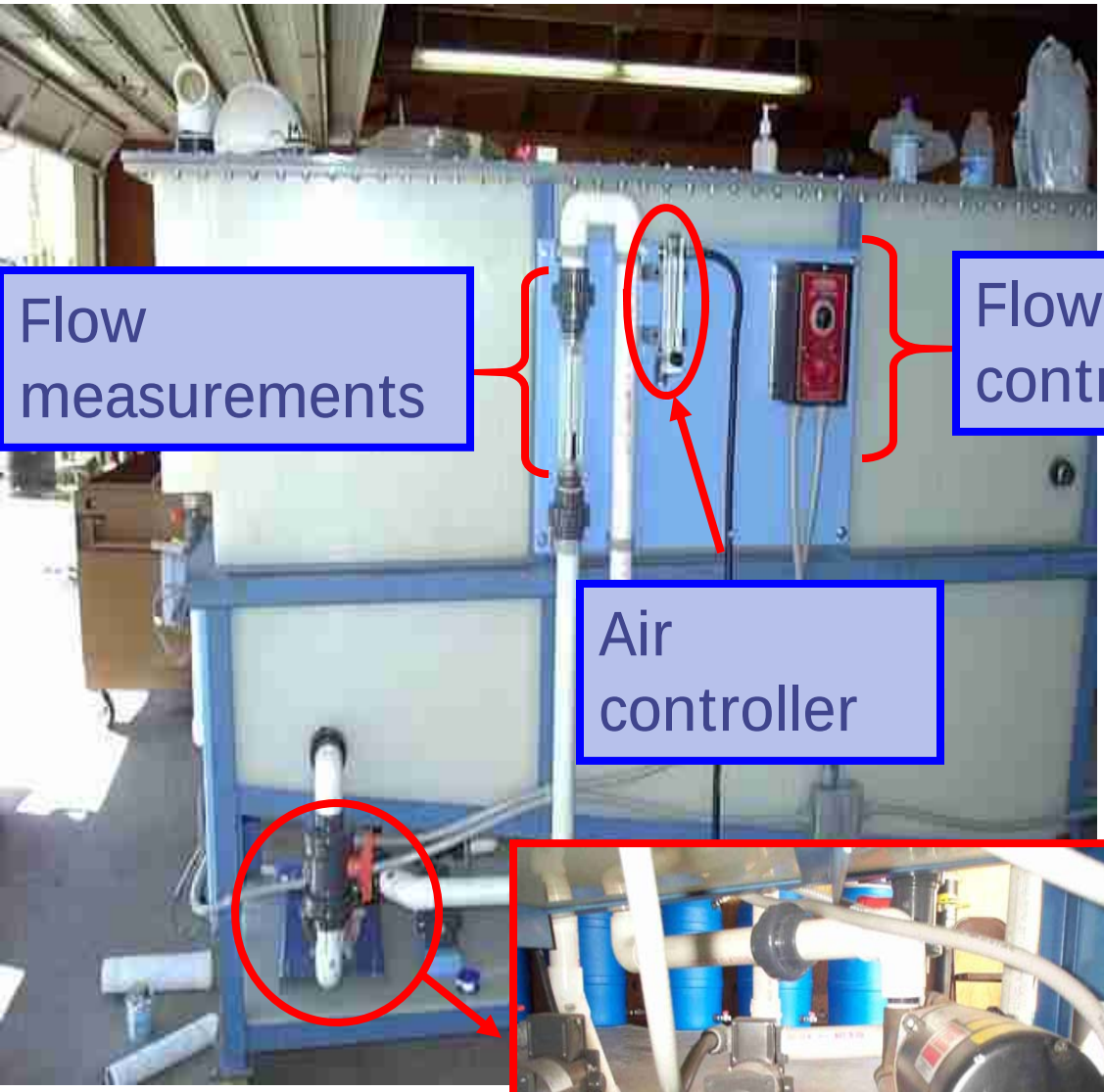

Acetic acid
Ammonium Phosphate
Inline mixer
Flow controller
Backwash Pump
Groundwater Feed Pump


CDM Camp Dresser & McKee
Groundwater mixed with acetic acid and nutrient



Penn State University

Figure 2
Treatment Phase



Air Scour Compressor

Backwash pump

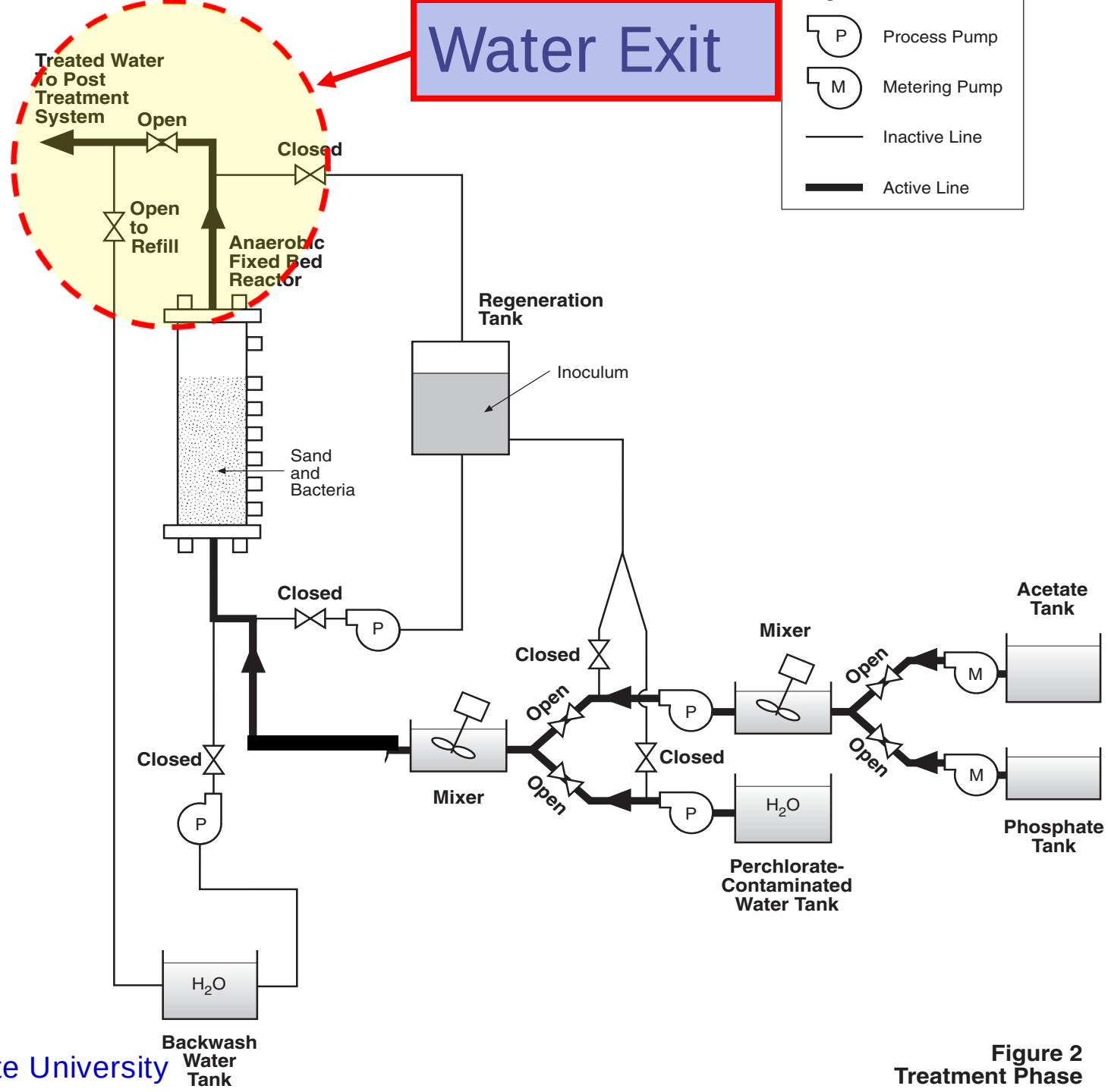
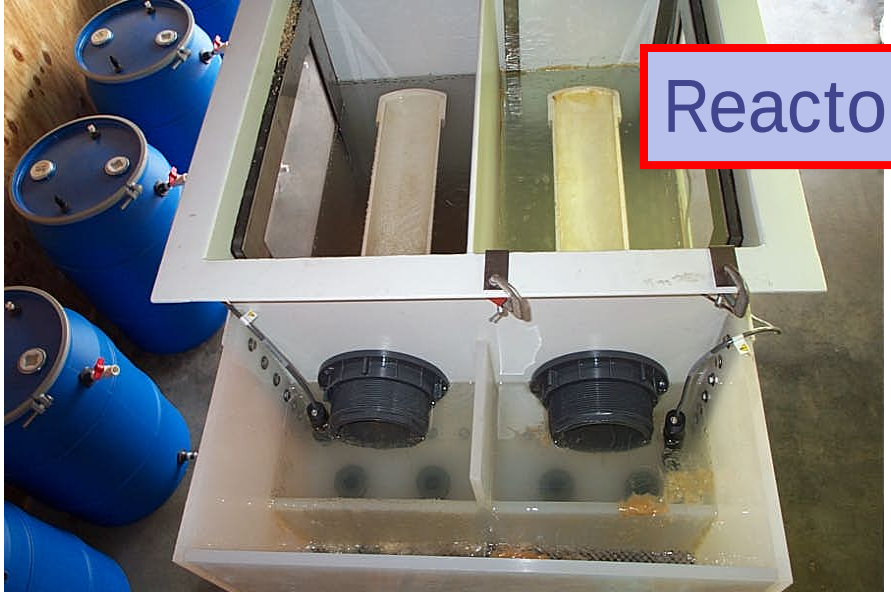


Figure 2
Treatment Phase

Flow of the Effluent



Reactor top

Holding tank

Sand media reactor

Sand (1 mm diameter)

Sampling position

On site measurements (Temp., pH, DO, Backpressure, ORP, and Turbidity)

YXI 600 XL instrument

Results

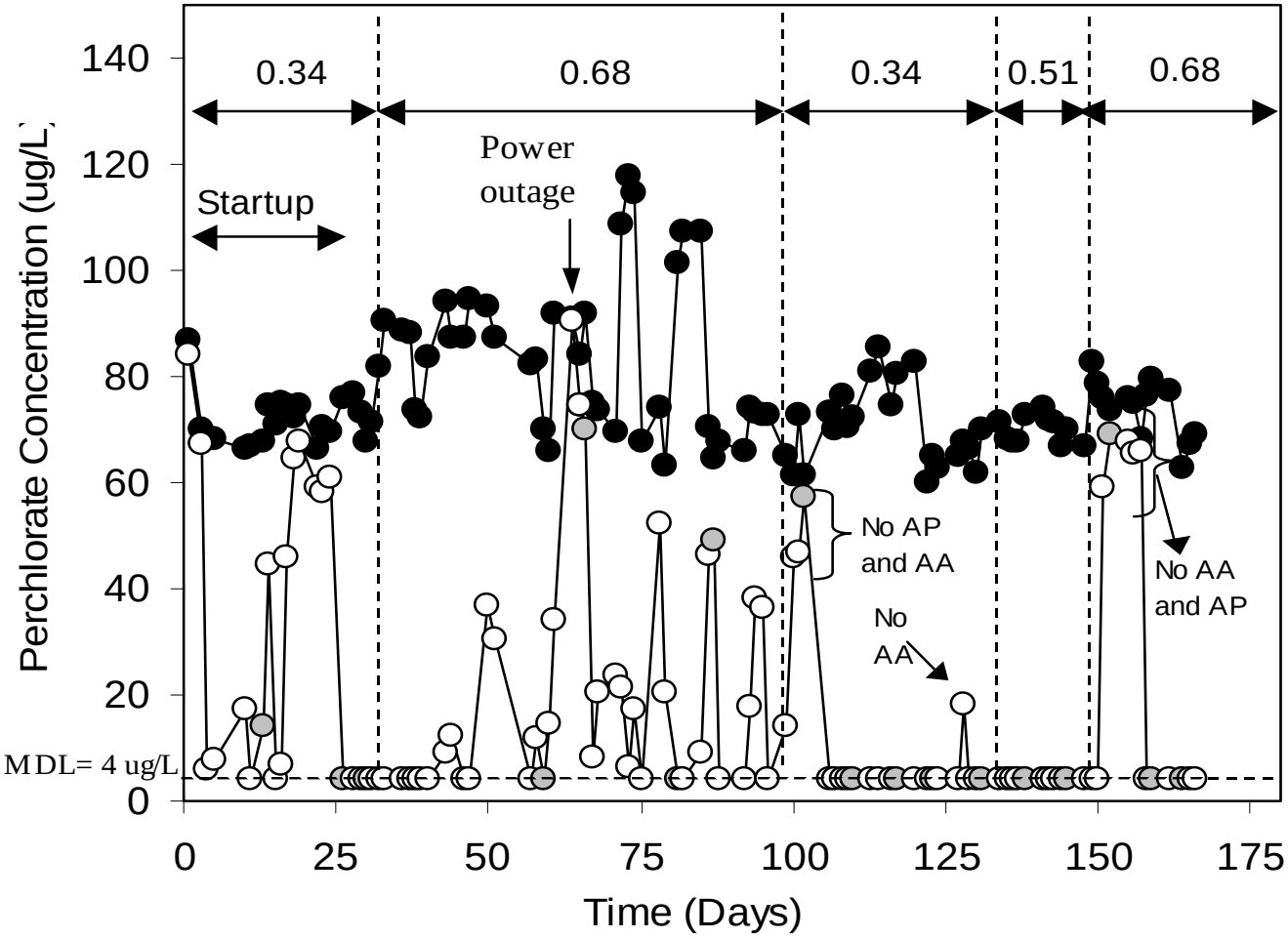
Groundwater Characteristics

Parameter	Value	Units
Perchlorate	73 ± 13	ug/L
Nitrate	4.0 ± 0.4	mg/L-N
Oxygen	7.5 ± 1.0	mg/L
TCE	3.7 ± 0.5	ug/L
1,1-DCE	1.2 ± 0.2	ug/L

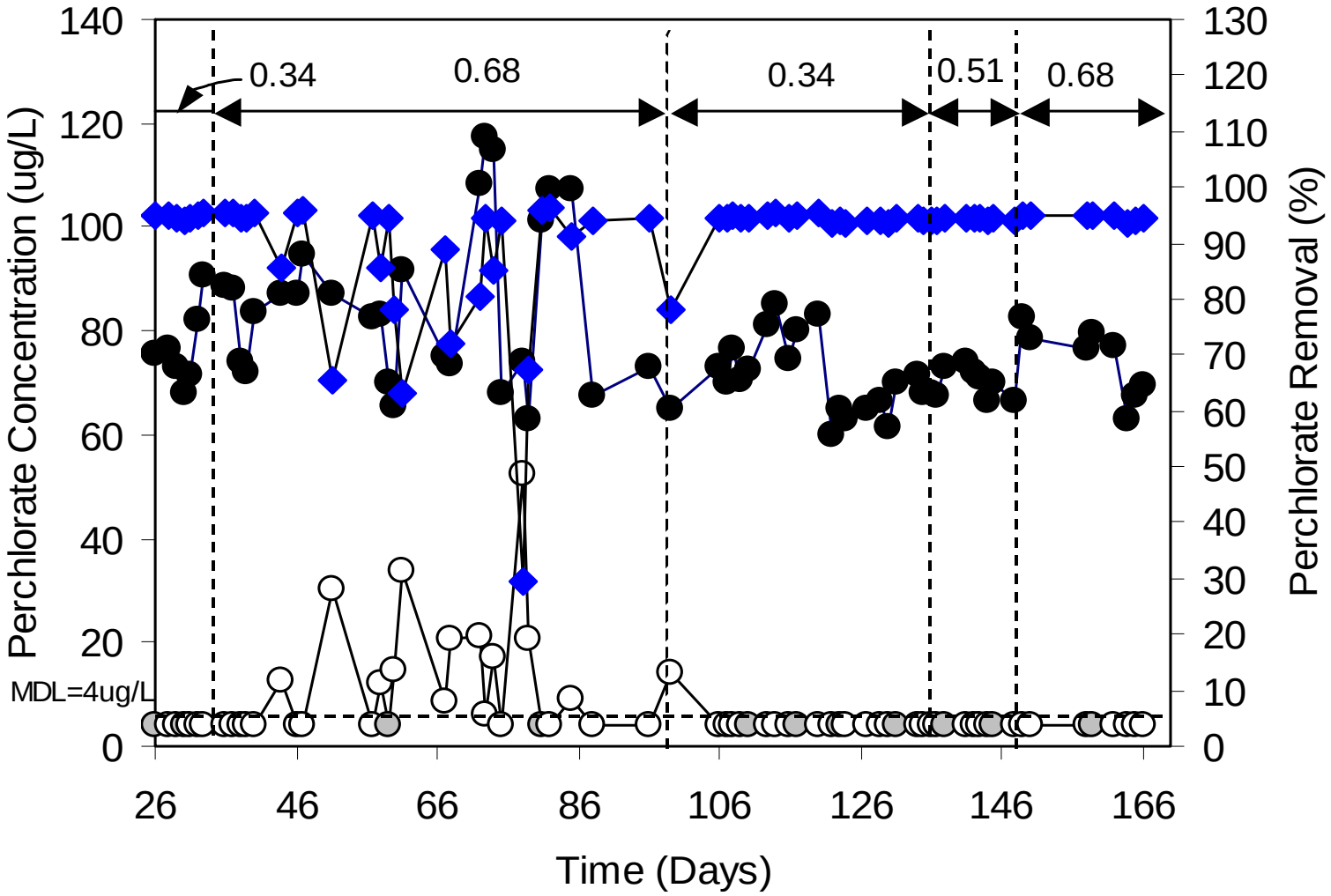
Acetic acid and Nutrients

Measurements	Influent	Effluent
Acetic acid (mg/L) pH	44 ± 8 6.74 ± 0.10	13 ± 8 6.86 ± 0.10
Phosphate (mg/L)	10.9 ±1.8	10.6 ±0.7
DOC (mg/L)- g.w. - reactor	0.28 15 ± 6	---- 6 ± 5
Turbidity (NTU)	----	1.75 ± 1.40

Perchlorate Raw data

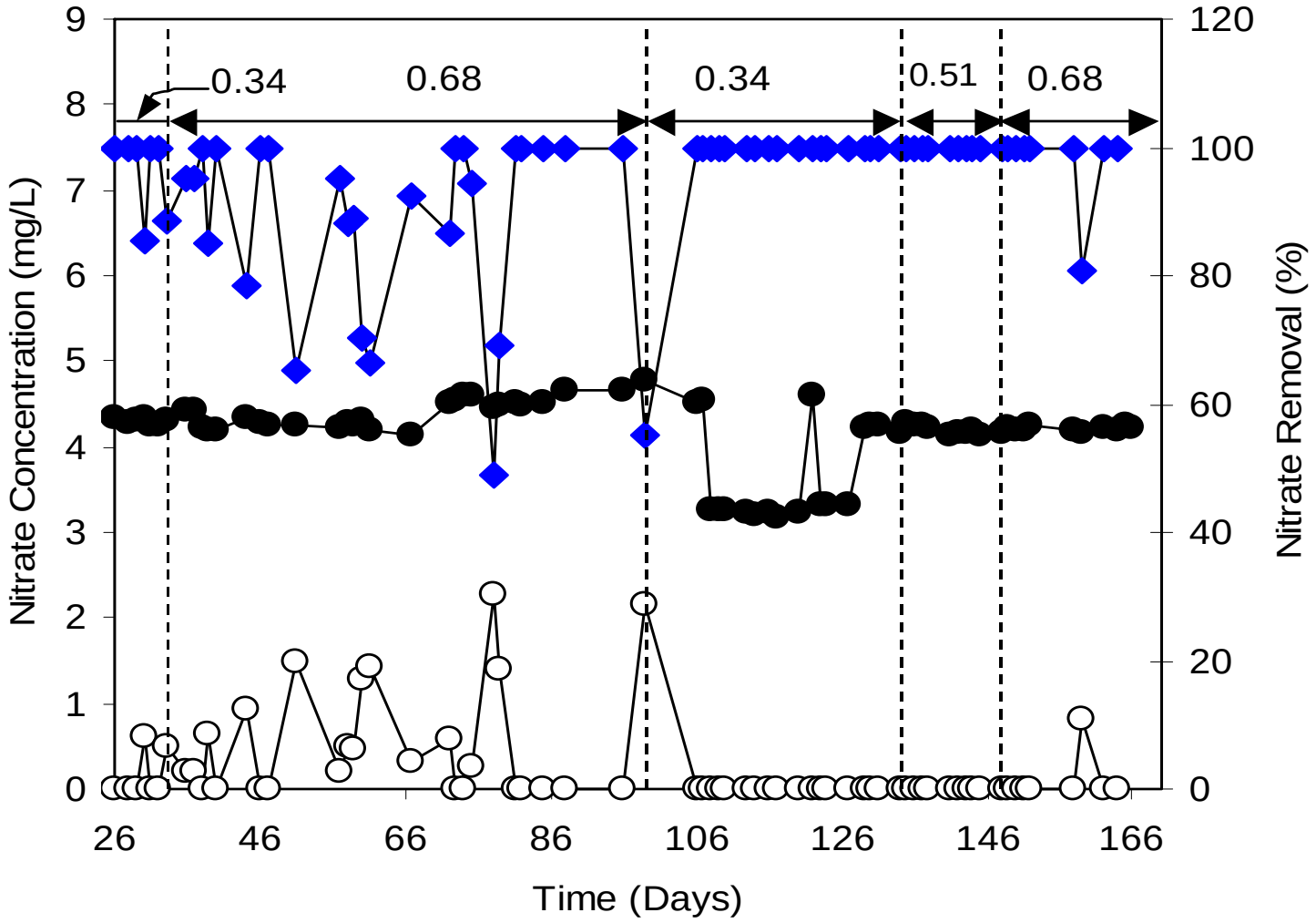


Perchlorate data on days of proper operation



=Reactor backwashed

Nitrate data on days of proper operation



Backwashing Reactor:

Remove excess biofilm

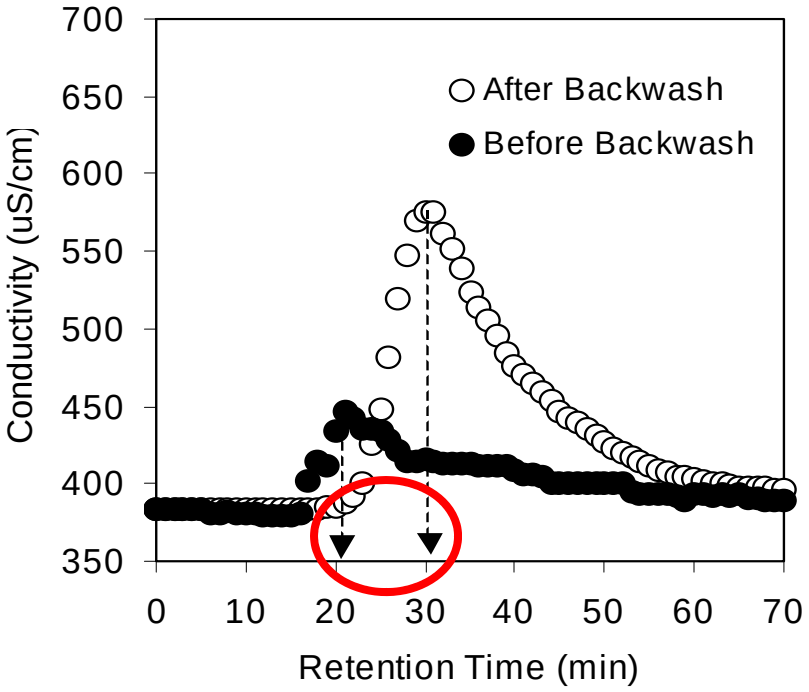
Redistribute the biofilm-covered media

Break up any clumps of biofilm

Retention time test

Before backwash: 21 min

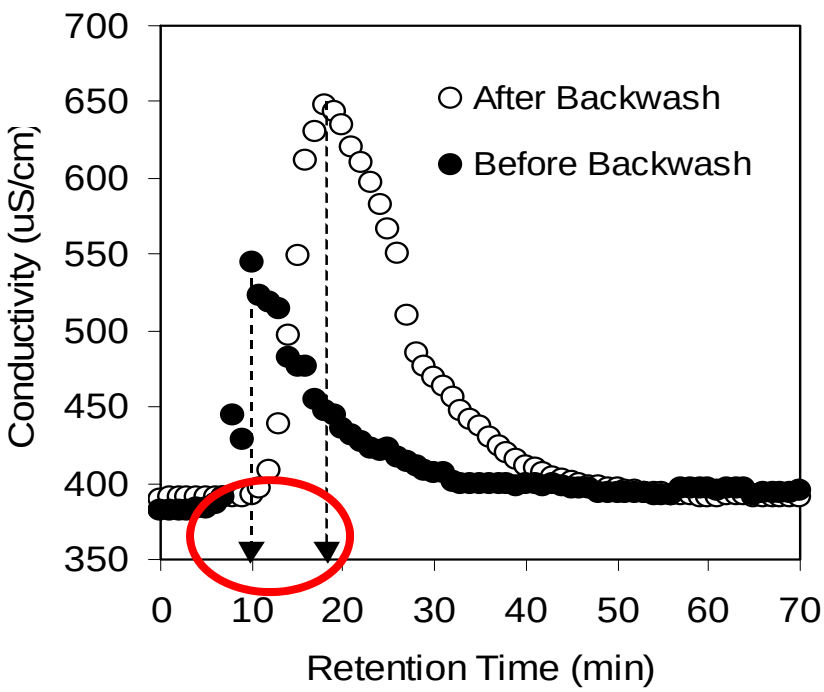
After backwash: 30 min



0.34 L/m^{2}s (day 110)

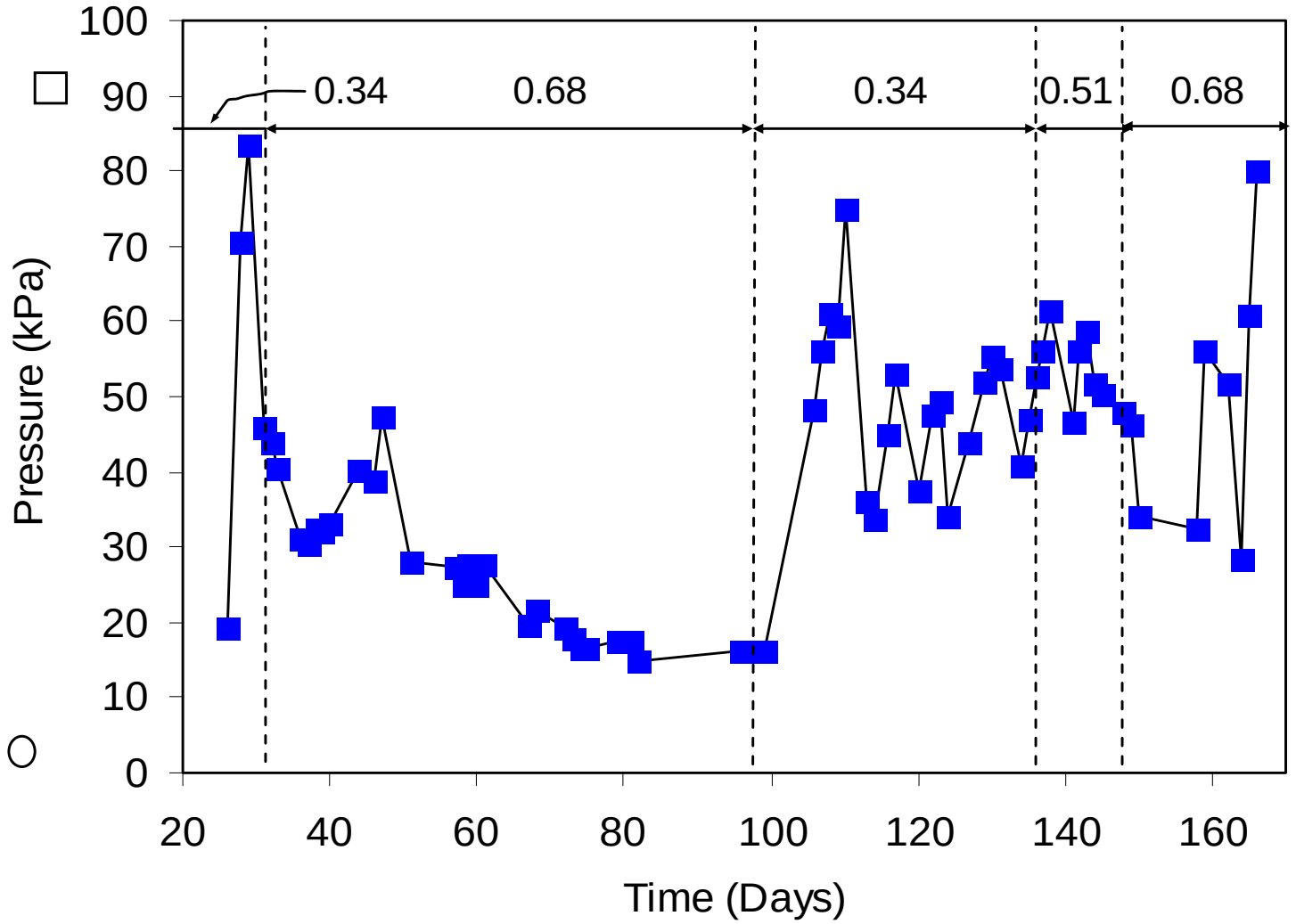
Before backwash: 10 min

After backwash: 18 min

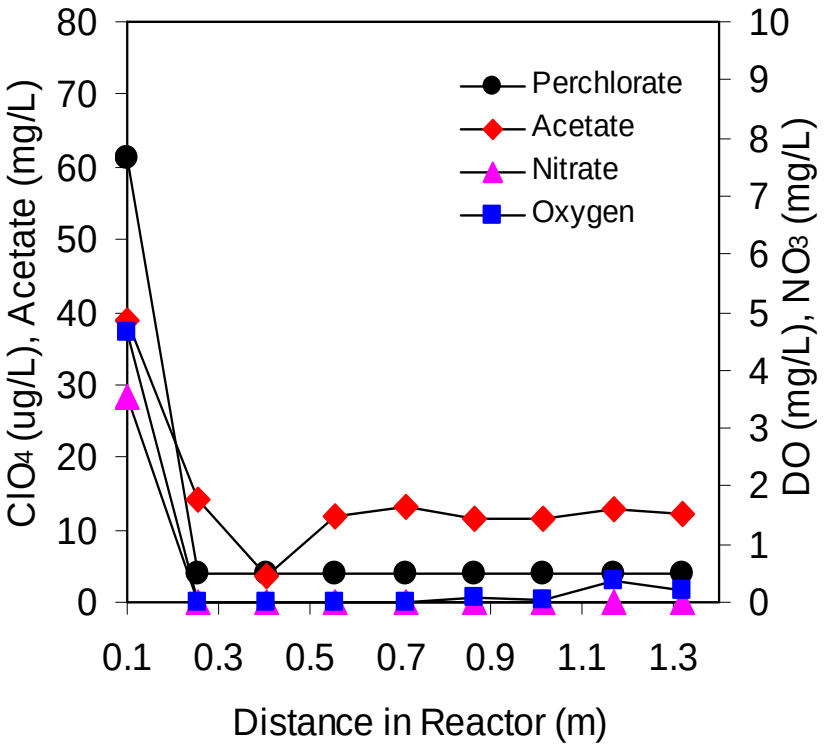


0.68 L/m^{2}s(day 138)

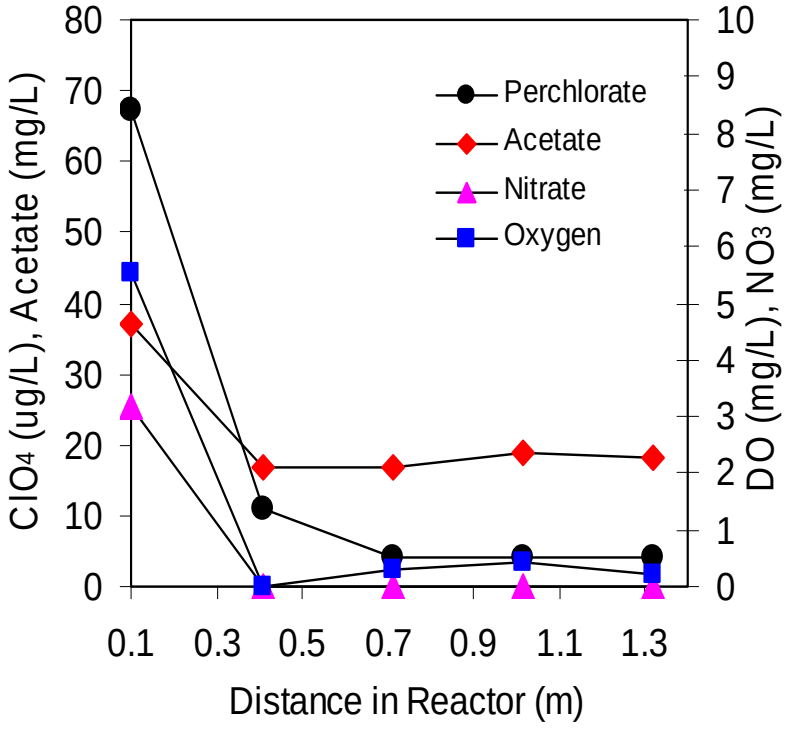
Backpressure data



Profiles of electron donor (acetate) and different electron acceptors (ClO_4^-, NO_3^-, O_2)



1 gpm (24 min. HRT)



2 gpm (12 min. HRT)

Conclusions

- Perchlorate was completely removed (<4 ug/L) in the sand medium bioreactor at flow rates of 0.063 to 0.126 L/s
- A regular backwashing cycle was necessary to achieve consistent reactor performance, especially at 0.126 L/s hydraulic loading rate.
- Consistent reactor performance was obtained by backwashing media regularly and continuous nutrient amendments.
- Nitrate and dissolved oxygen were also completely removed by the reactor.

Acknowledgments

City of Redlands	Doug Hedricks, Dave Commons, Ken Pang
Camp, Dresser & McKee, Inc.	Allyson Chu, Steven Price, Stephen Liao, Harold Pepple, Dick Corneille, Mike Zaefer
Students	Yanguang Song, Husen Zhang
Funding	AWWARF: Project manager Frank Blaha

REFERENCES

Logan, B.E. 2001. *J. Environ. Engng.* 127(5):469-471.

Logan, B.E., K. Kim and S. Price. 2001. *In:* Bioremediation of Inorganic Compounds, A. Leeson et al. eds. Battelle Press, Columbus, OH. 6(9):303-308.

Evans, P., A. Chu, S. Liao, S. Price. B. Min and B.E. Logan. 2002. Proc. Third International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 20-23, Monterey, CA. *In press.*

Min, B., P. Evans, A. Chu, and B.E. Logan. Perchlorate removal in a pilot plant-scale packed bed bioreactor- 1: Sand medium bioreactor. *Submitted.*