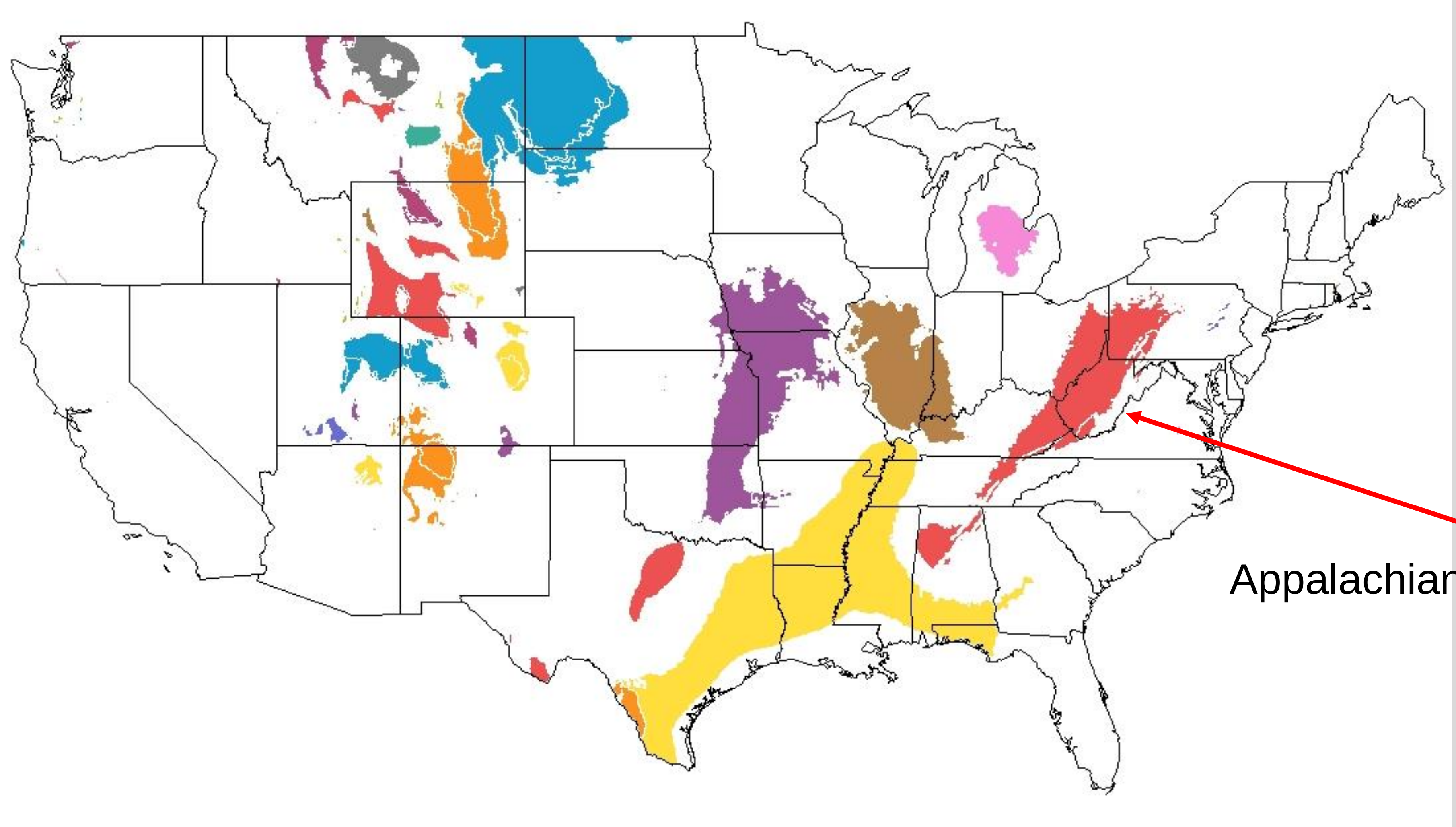
Co-treatment of Acid Mine Drainage in Municipal Wastewater Plants for Sustainable Design in Reclamation

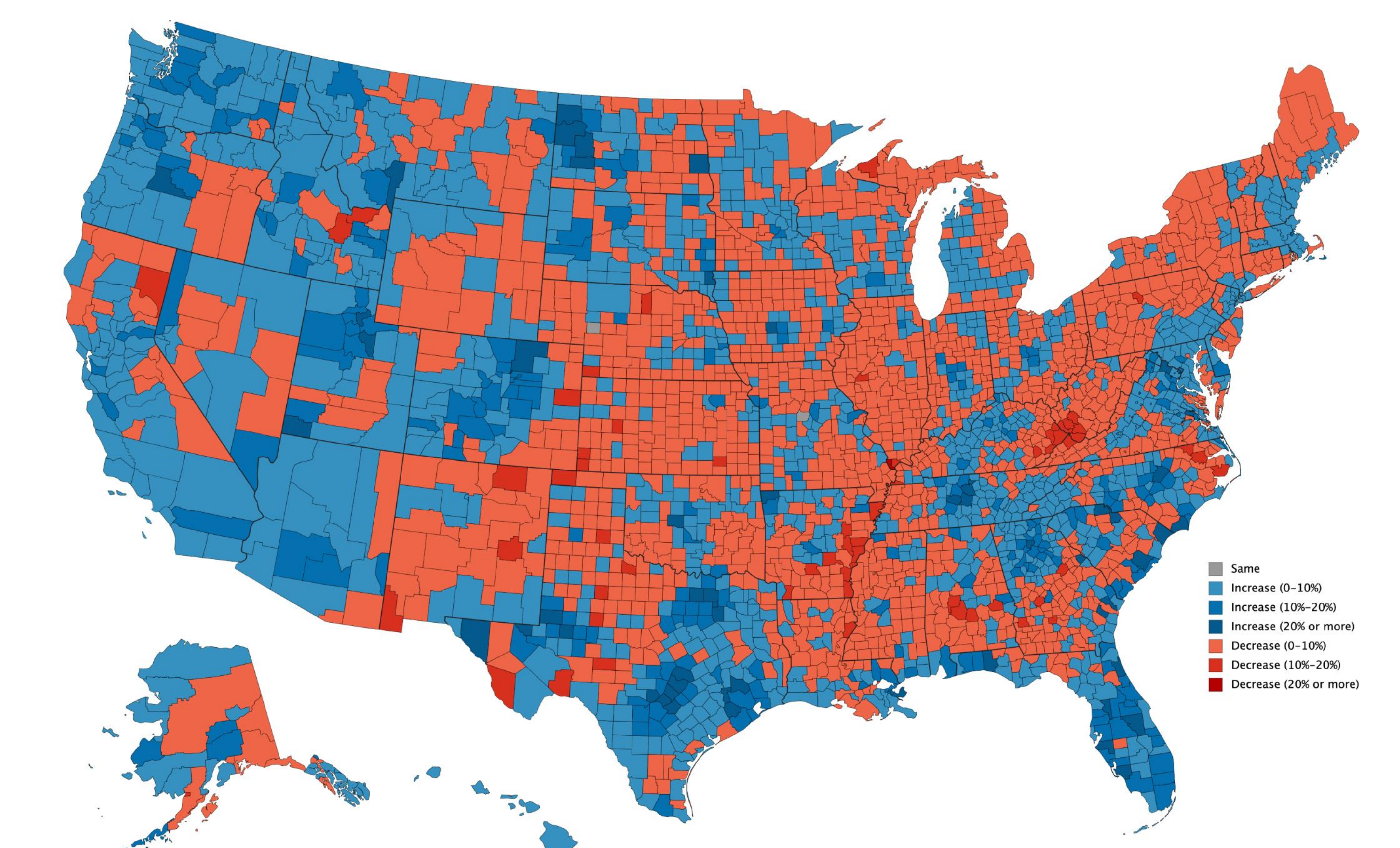
B. Roman, C.D. Spellman Jr., T. Tasker, W.H.J. Strosnider, and J.E. Goodwill

Coal fields are spread across the United States



Appalachian Region

In Appalachian Region, population is decreasing



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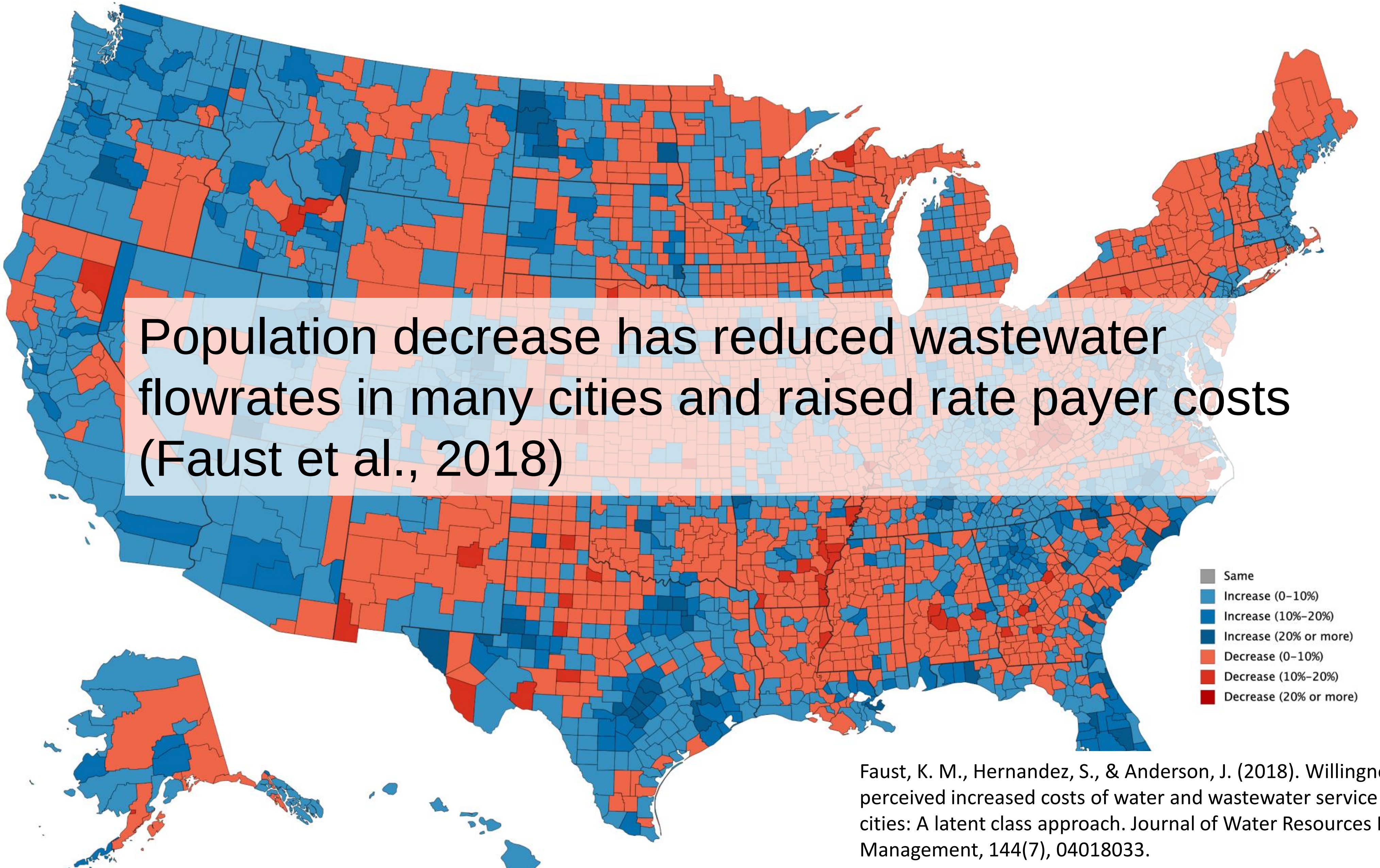
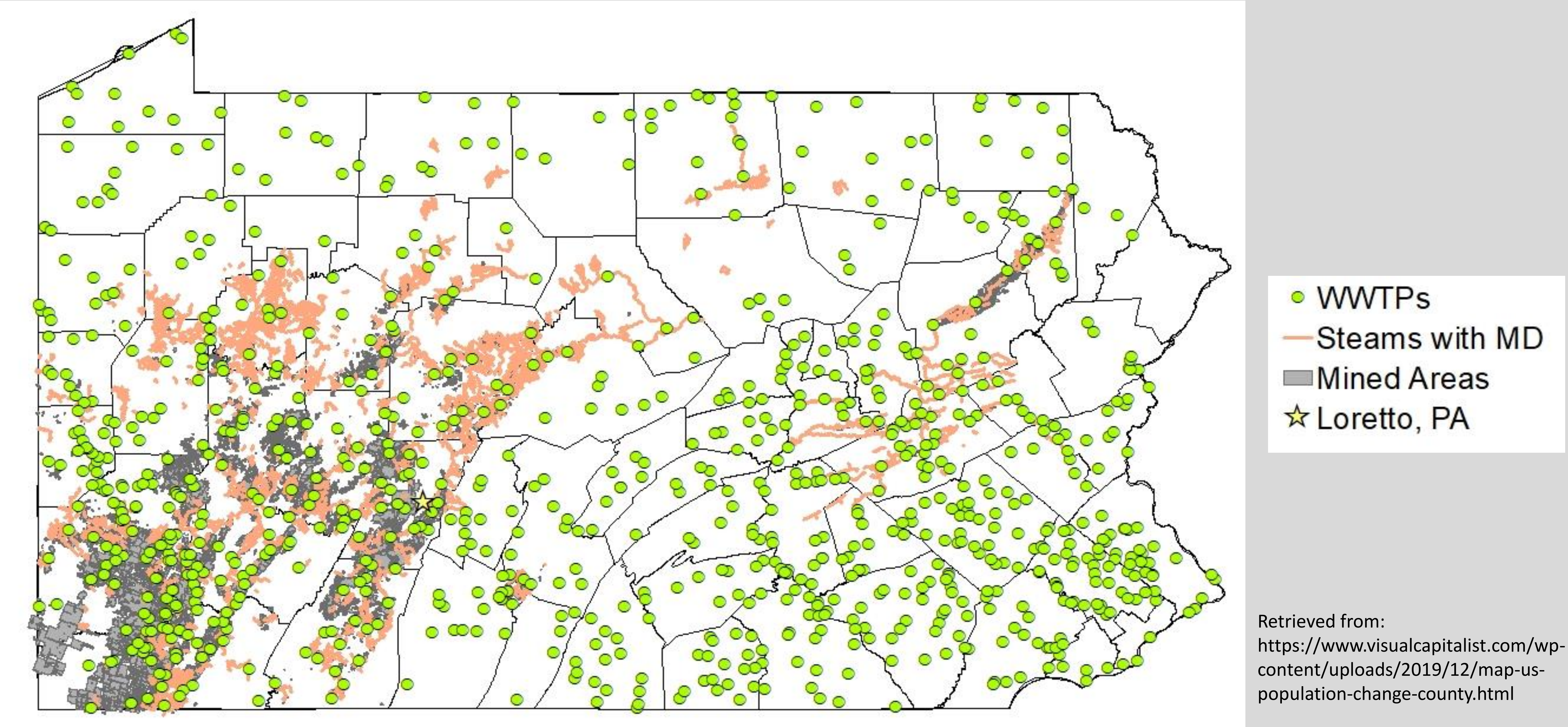


Population decrease has reduced wastewater flowrates in many cities and raised rate payer costs (Faust et al., 2018)

Faust, K. M., Hernandez, S., & Anderson, J. (2018). Willingness to pay for perceived increased costs of water and wastewater service in shrinking US cities: A latent class approach. Journal of Water Resources Planning and Management, 144(7), 04018033.

Wastewater Treatment Plants (WWTPs) in areas of population decline are close to Acid Mine Drainage



Retrieved from: https://www.visualcapitalist.com/wp-content/uploads/2019/12/map-us-population-change-county.html

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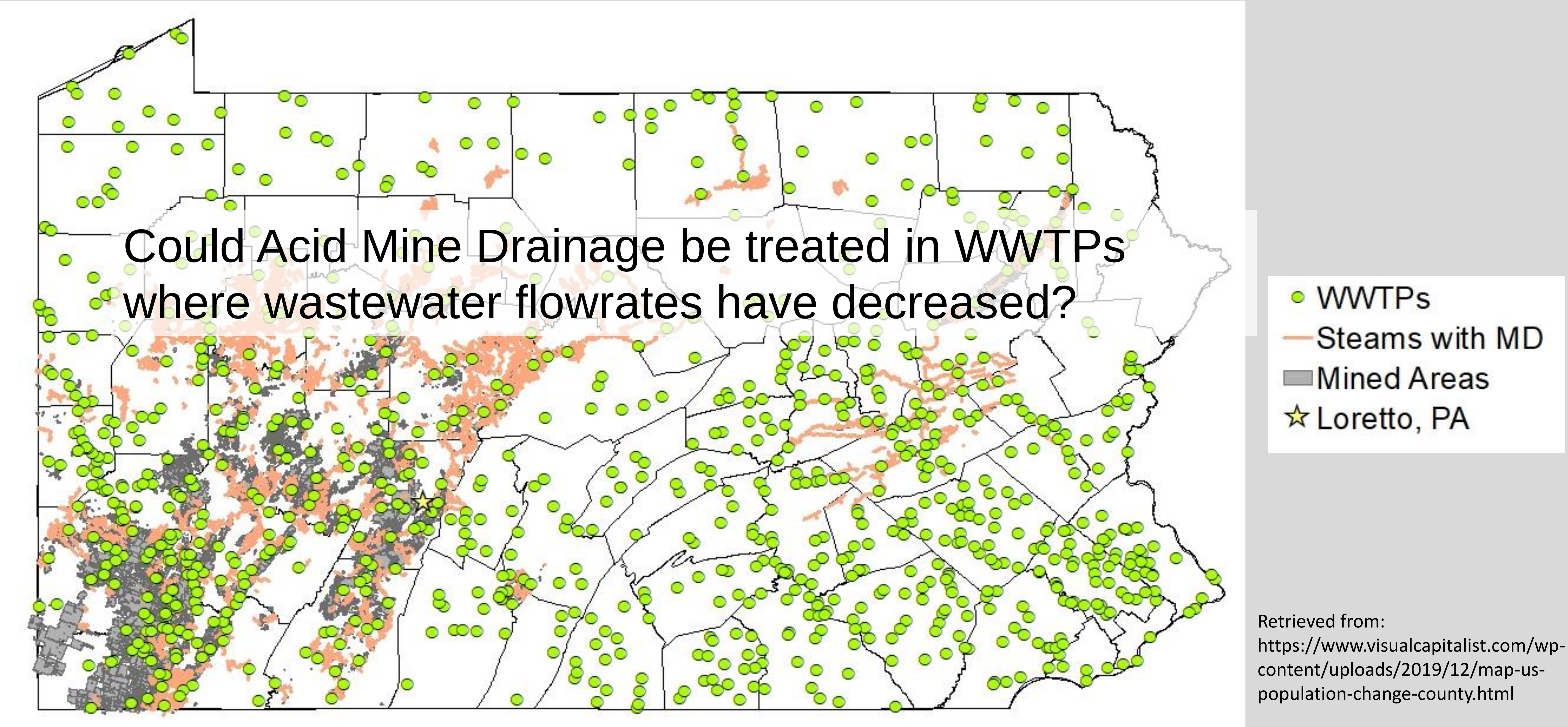

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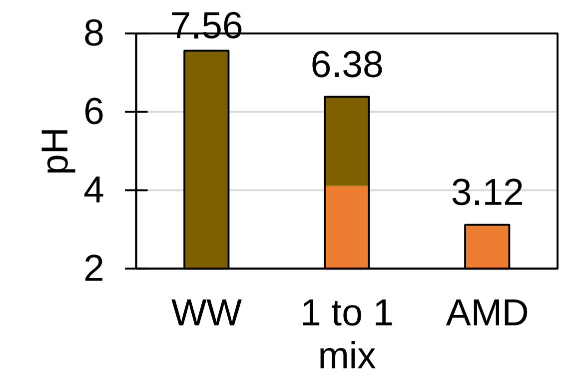
Hypothesis: AMD could be treated in existing wastewater treatment systems

WW pH = 6-8

WW alkalinity = 250 mg/L



PO_4^{3-} precipitation with iron and aluminum by mineral formation or adsorption to metal oxides:

$Fe^{3+} + PO_4^{3-} \rightarrow FePO_{4(s)}$ $Fe(OH)_{3(s)} \cdot PO_4$

$Al^{3+} + PO_4^{3-} \rightarrow AlPO_{4(s)}$ $Al(OH)_{3(s)} \cdot PO_4$

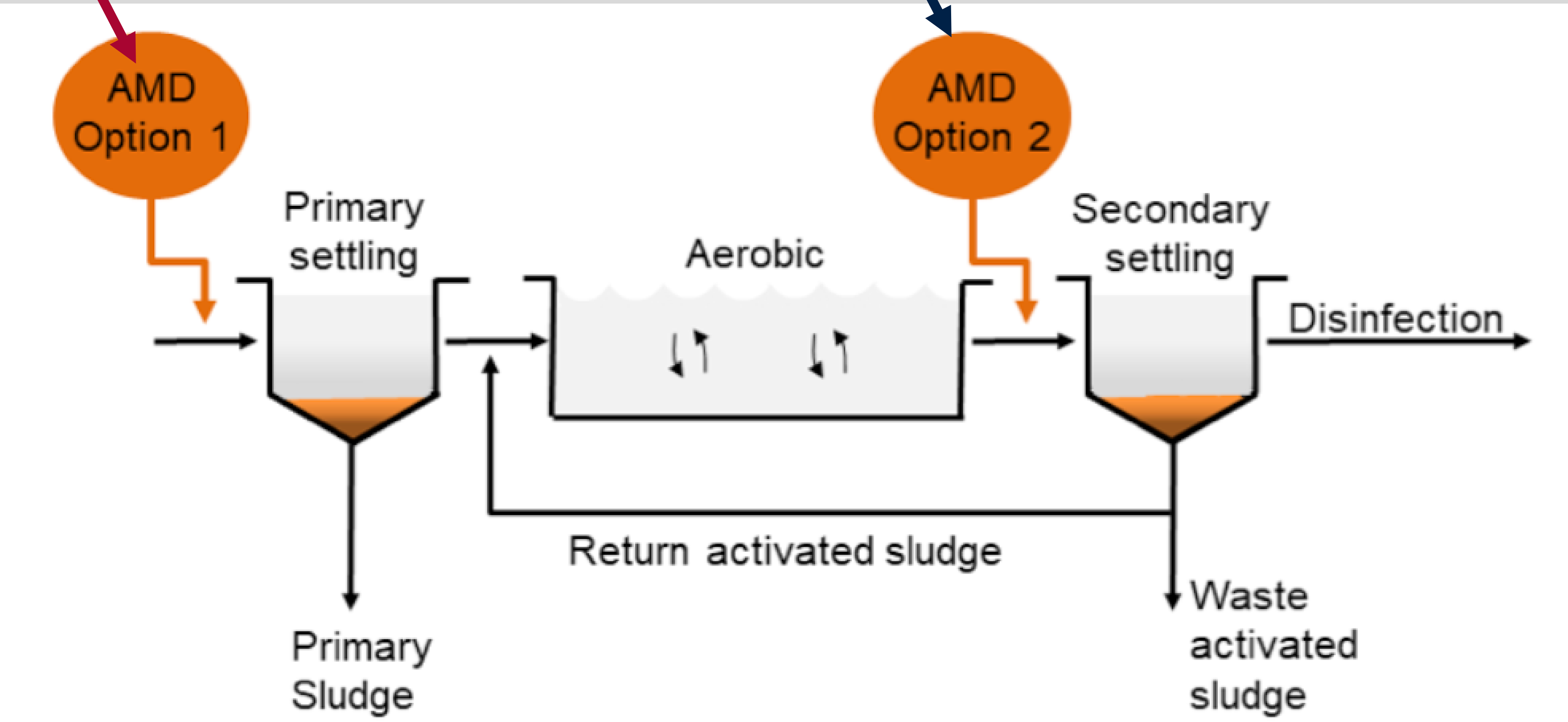
How will adding AMD to a wastewater treatment system impact its performance?

Credit: Travis Tasker

The project involves analyzing the impacts of adding AMD to two locations within the treatment system

Saint Francis University (This work)

University of Rhode Island



AMD discharges were mixed with WW from the SFU WWTP in 10% and 40% AMD to WW ratios

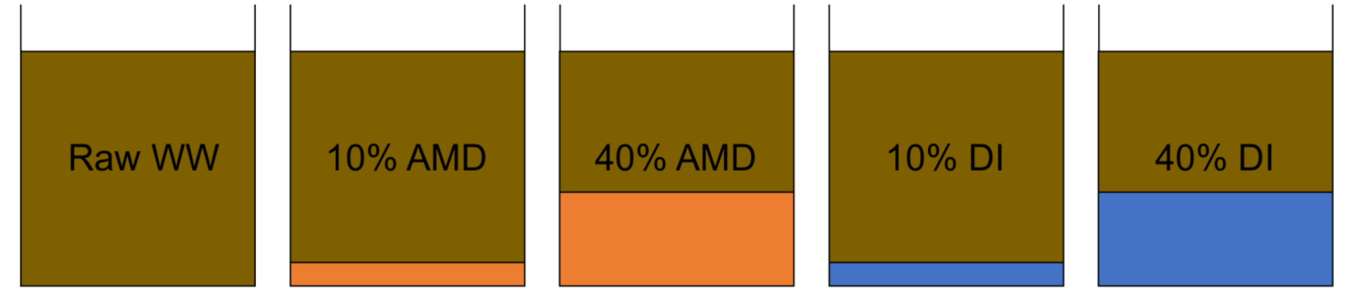
WW+AMD Solutions were mixed for 2 minutes and settled for 2 hours

After two hours, the supernatant from each reactor was analyzed for:
- pH
- metals concentrations
- phosphate concentrations

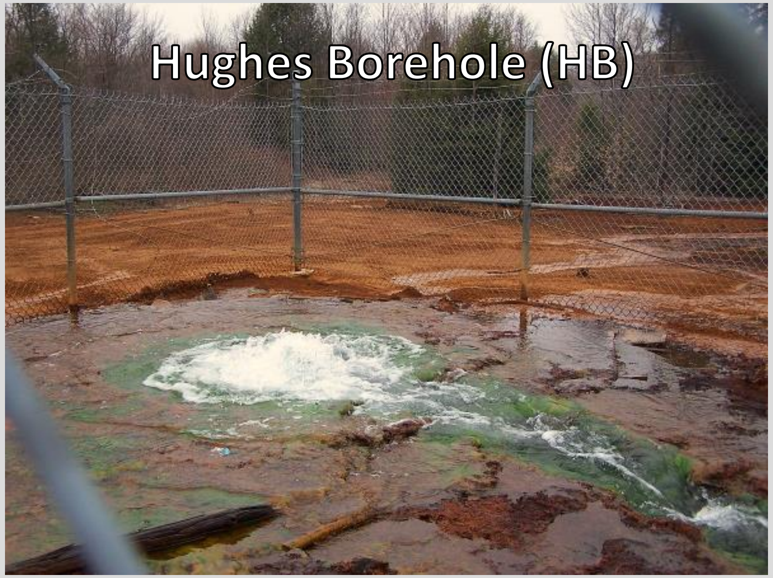
BOD removal rates were determined using HACH BOD Trak II respirometers

$$BOD_t = UBOD * \left(1 - e^{-kt}\right)$$

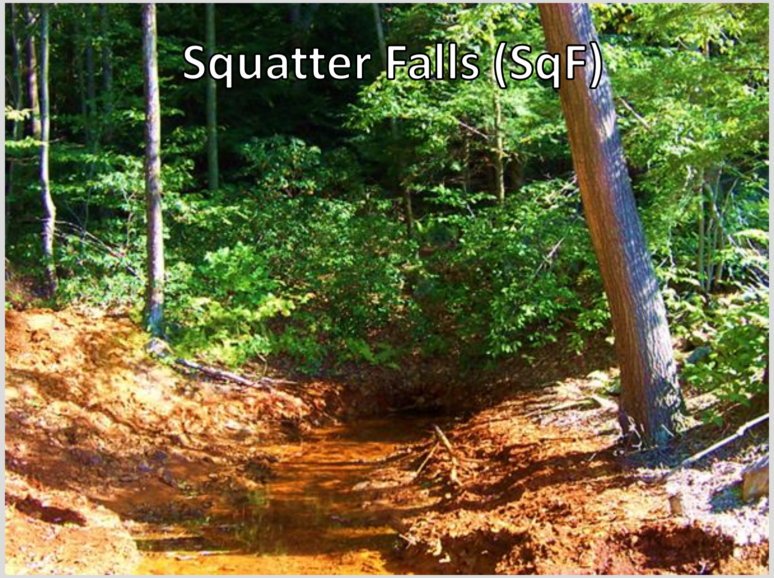
where,
BOD_t = BOD at time t (mg/L)
UBOD = Ultimate BOD (mg/L)
k = first-order reaction rate (day^{-1})
t = time (day)



Three AMD sites with varying iron and aluminum concentrations were considered:



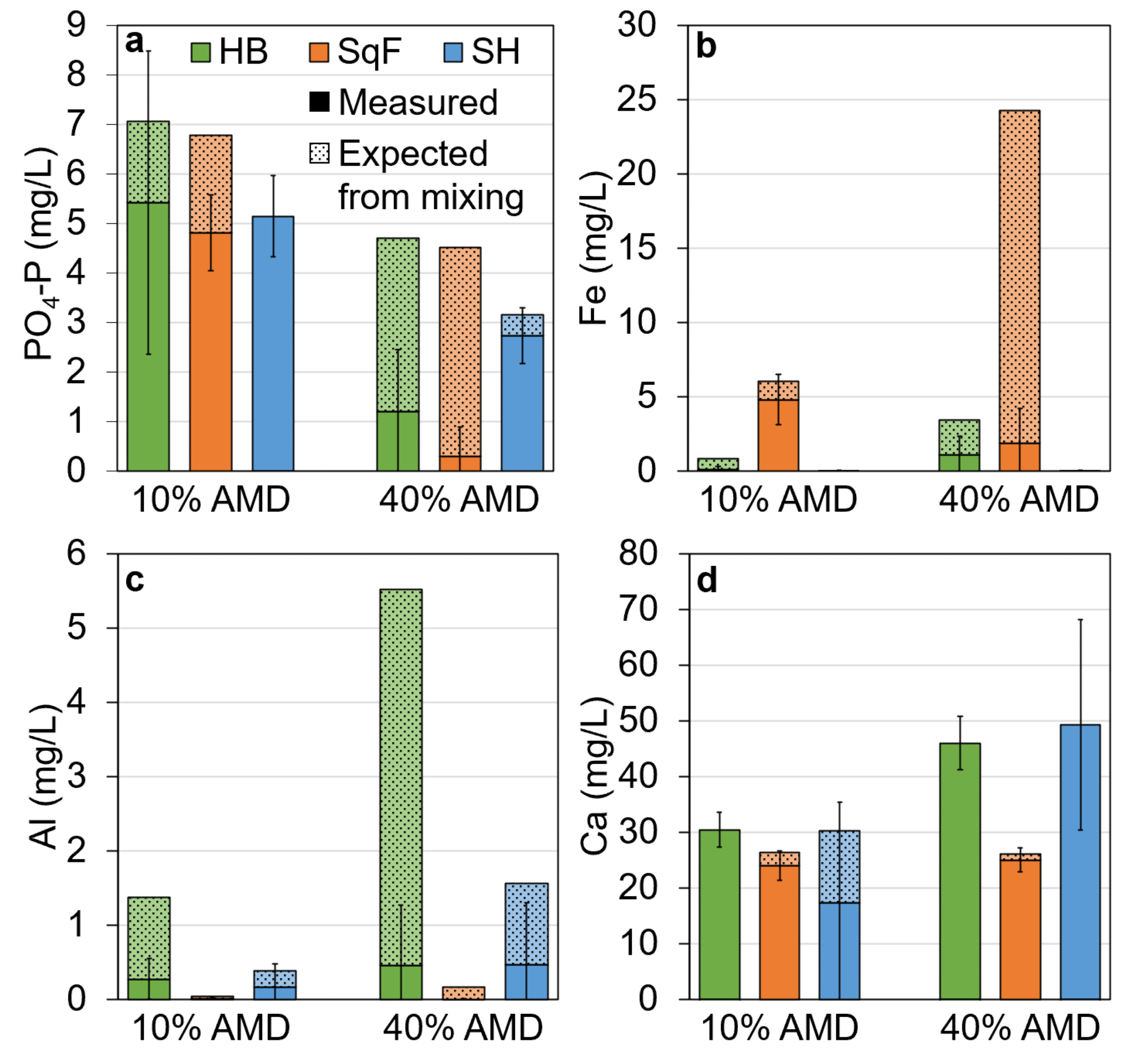
Constituent	Average ± *Standard Deviation*
pH	3.22 ± *0.05*
Iron (mg/L)	**8.67 ± *7.04***
Aluminum (mg/L)	**13.8 ± *1.01***
Calcium (mg/L)	69.0 ± *7.62*

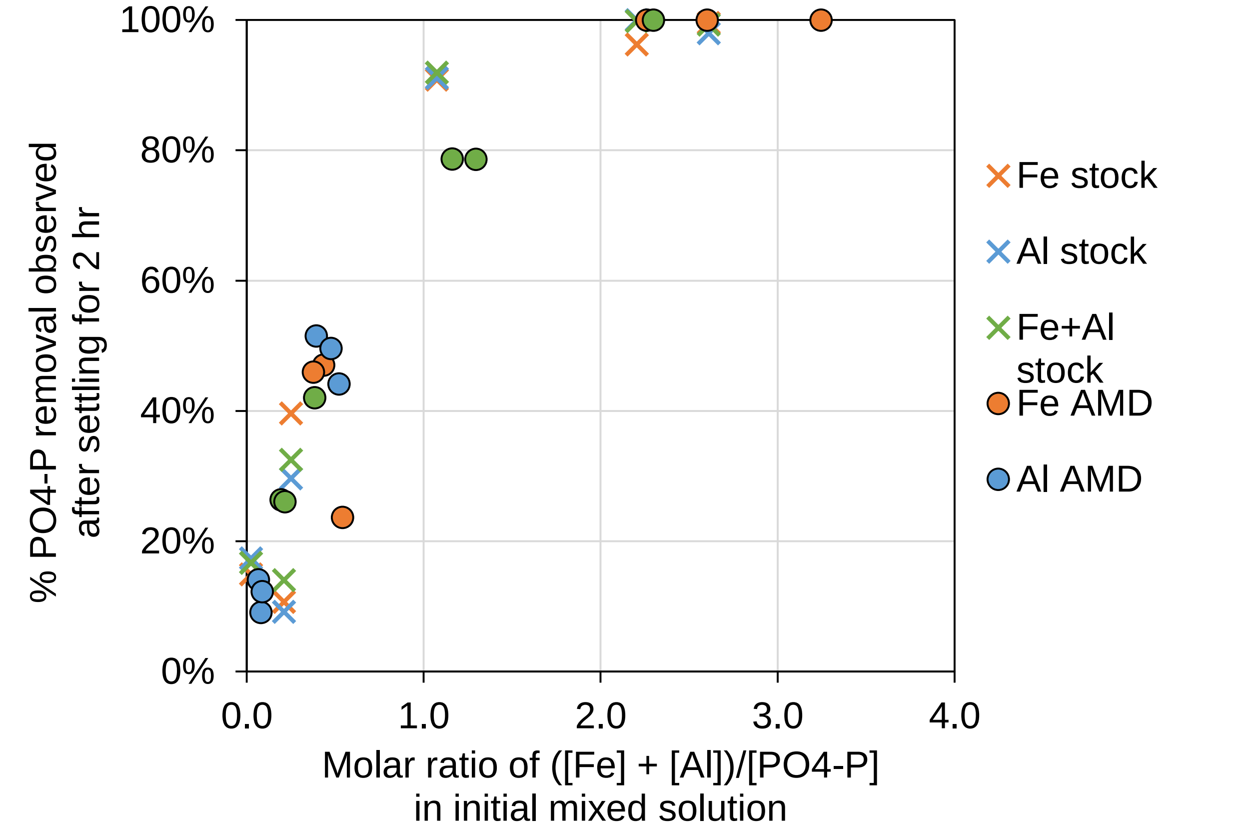


Constituent	Average ± *Standard Deviation*
pH	4.42 ± *0.31*
Iron (mg/L)	**60.6 ± *4.65***
Aluminum (mg/L)	0.43 ± *0.11*
Calcium (mg/L)	25.3 ± *0.91*

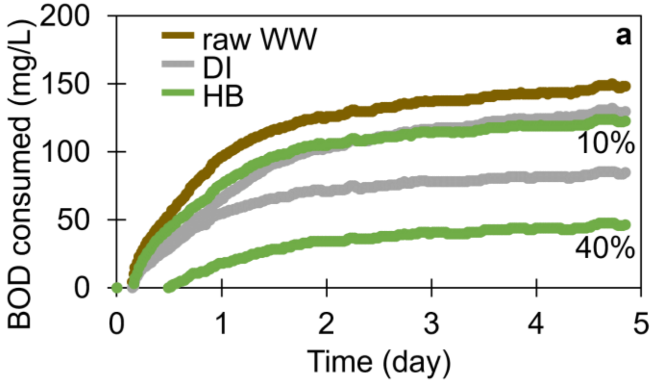
Constituent	Average ± *Standard Deviation*
pH	4.01 ± *0.03*
Iron (mg/L)	Below Detection
Aluminum (mg/L)	**3.92 ± *0.91***
Calcium (mg/L)	85.2 ± *7.49*

Phosphate removal was greater than expected from mixing for all but the 10% Spaghetti Hole (SH) reactor.

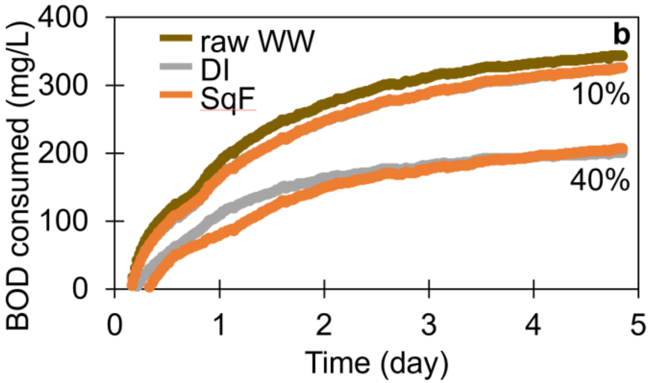




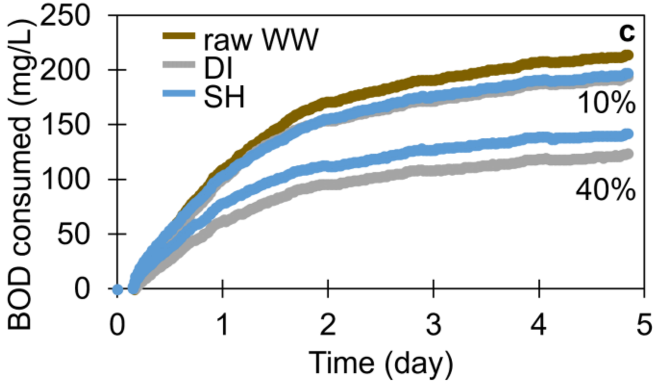
BOD removal in the AMD solutions followed a similar consumption profile to the DI solutions.



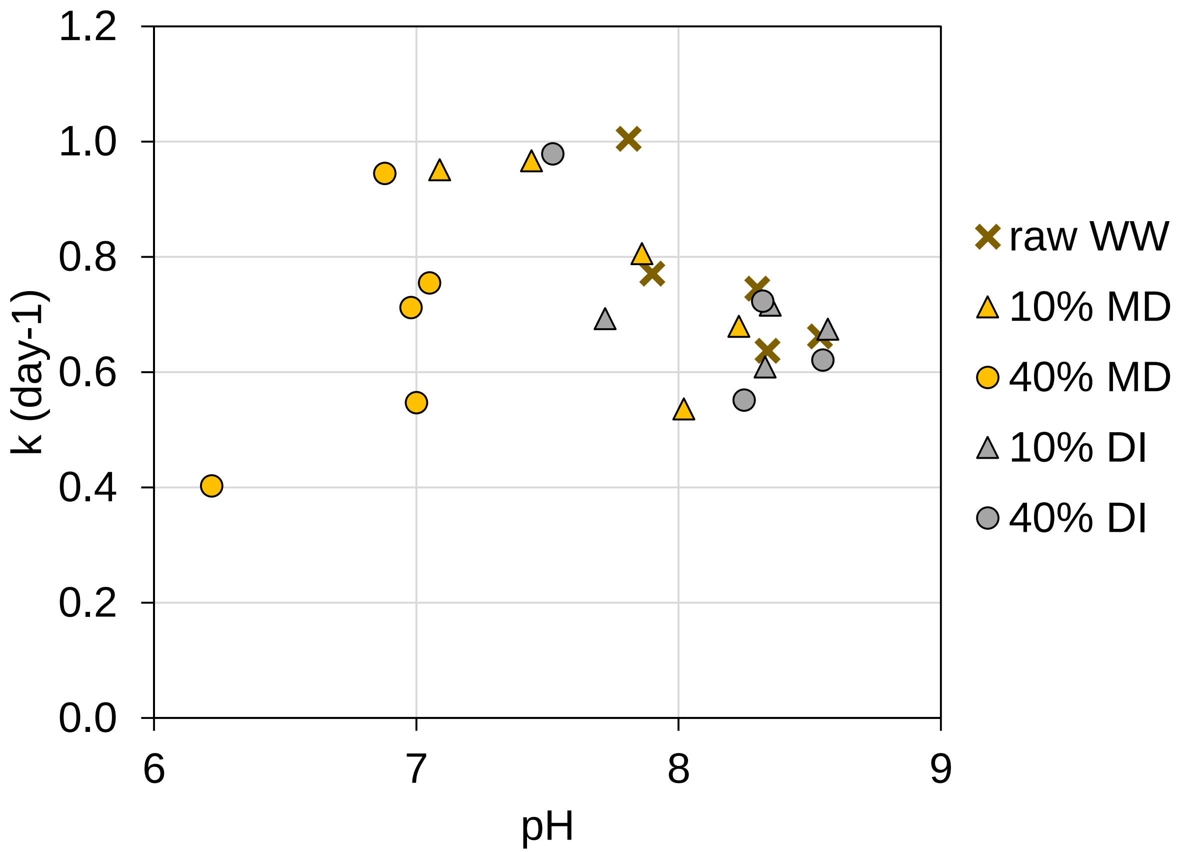
Reactor	*k* (day^{-1})	UBOD (mg/L)	pH
raw WW	1.00	146	7.81
10% DI	0.69	134	7.72
10% HB	0.95	123	7.09
40% DI	0.98	83.6	7.52
40% HB	0.40	56.1	6.22



Reactor	*k* (day^{-1})	UBOD (mg/L)	pH
raw WW	0.74	351	8.45
10% DI	0.65	338	8.44
10% SqF	0.65	338	7.75
40% DI	0.72	208	8.40
40% SqF	0.45	236	6.98



Reactor	*k* (day^{-1})	UBOD (mg/L)	pH
raw WW	0.67	223	7.90
10% DI	0.69	200	7.88
10% SH	0.70	203	7.44
40% DI	0.64	128	7.92
40% SH	0.73	145	6.88



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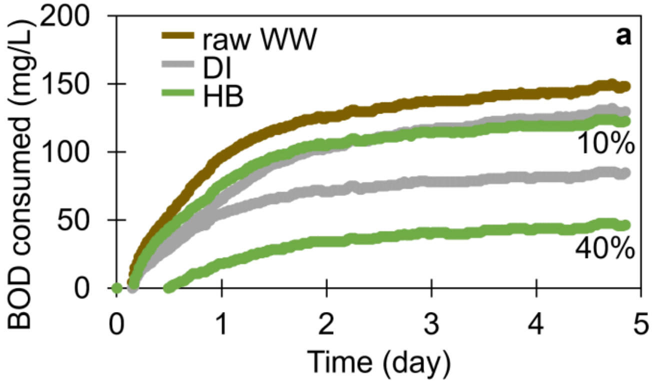

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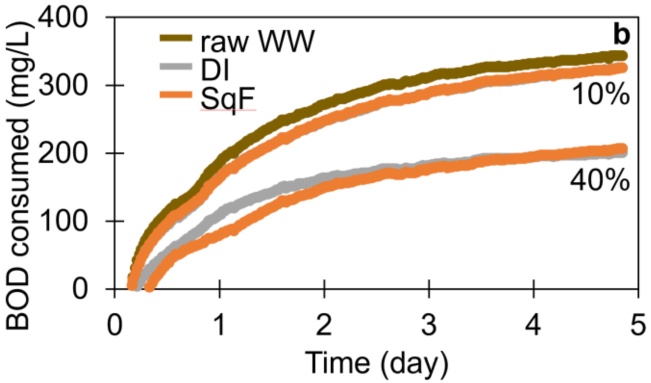

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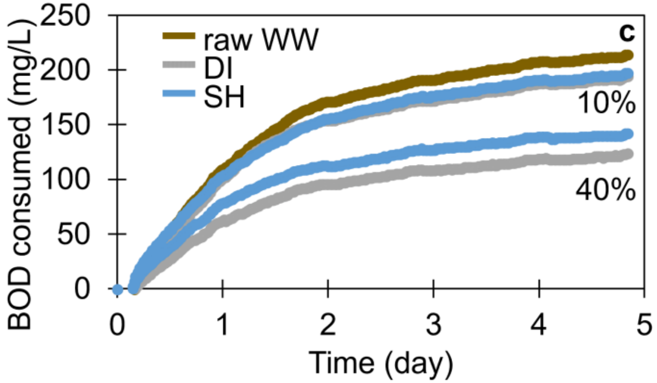

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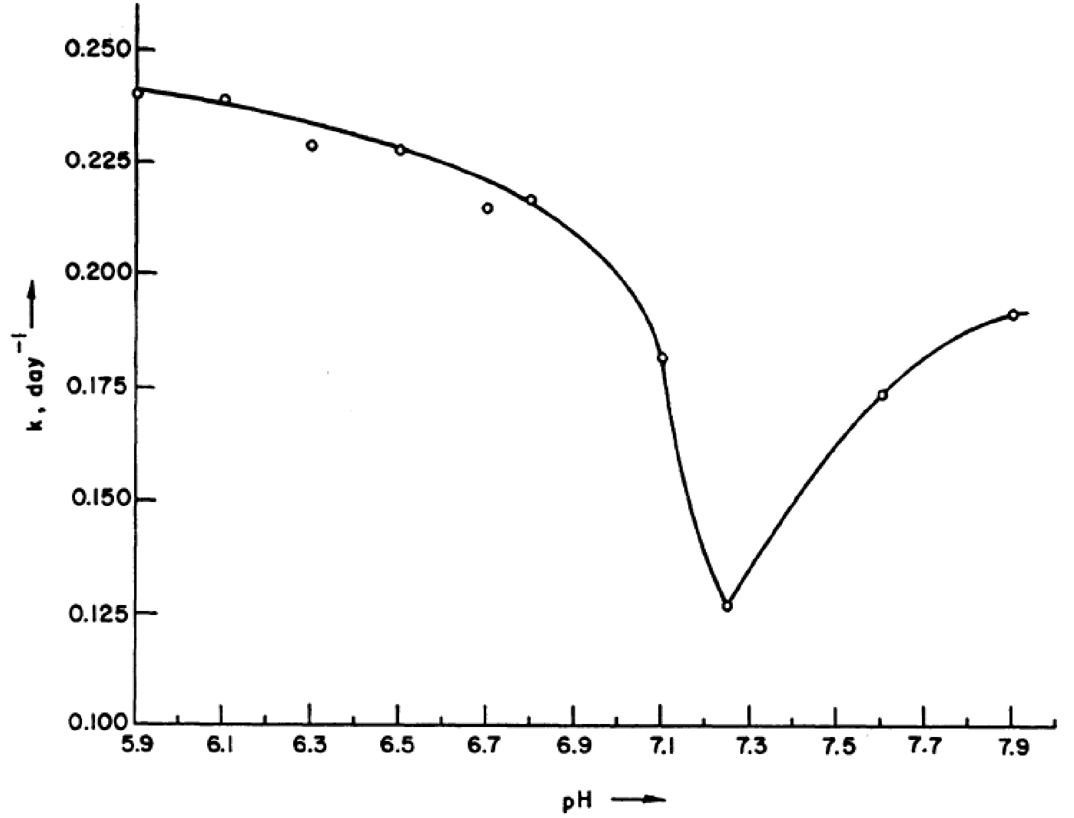
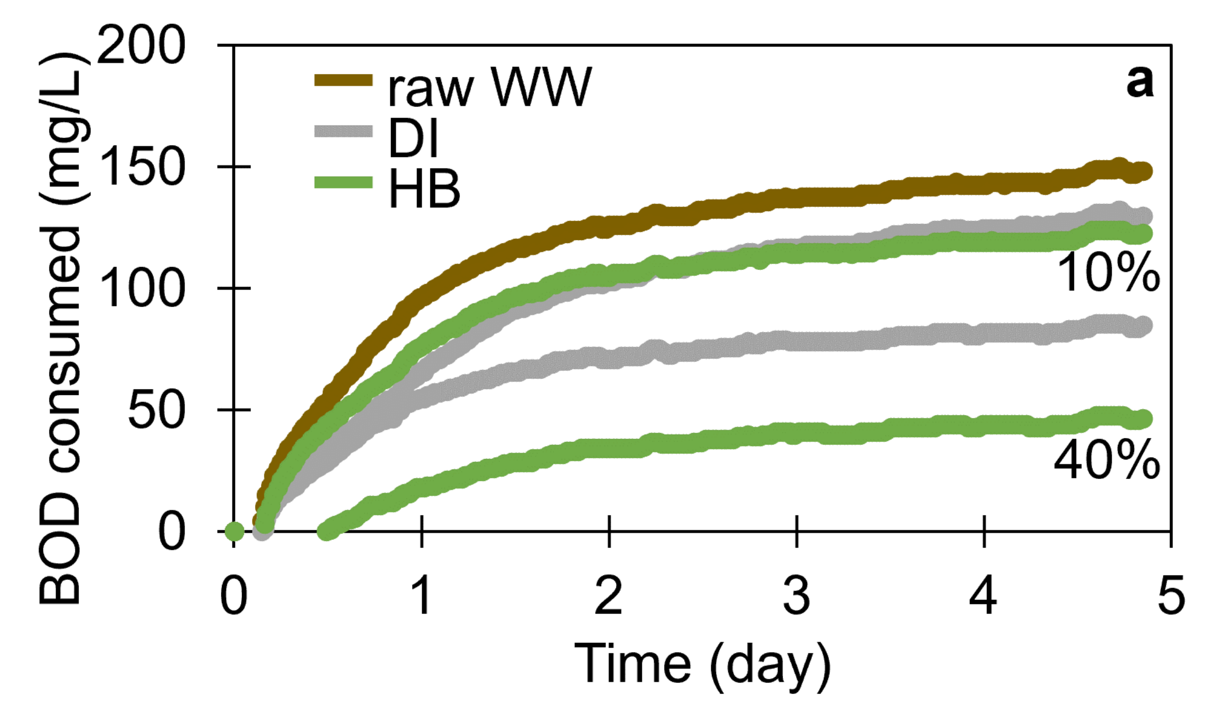


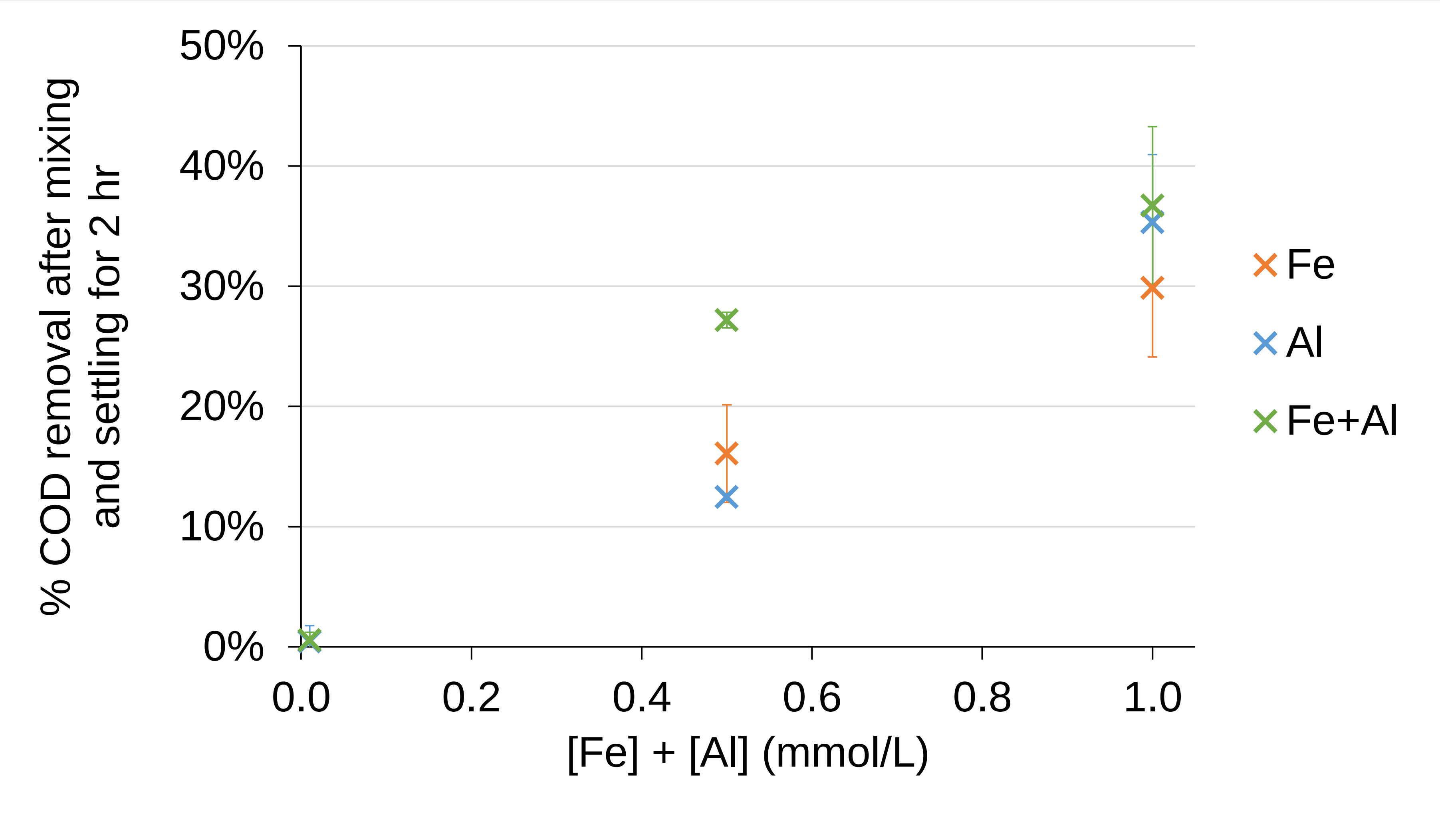
FIGURE 1.—Rate constant, *k*, of sample E at 20° C is shown as a function of pH.

Mukherjee et al. (1968) Effect of pH on the Rate of BOD of Wastewater. *Journal Water Pollution Control Federation*, 40(11)

Sweep coagulation was observed in the 40% HB reactor, which decreased the UBOD by over 30%.



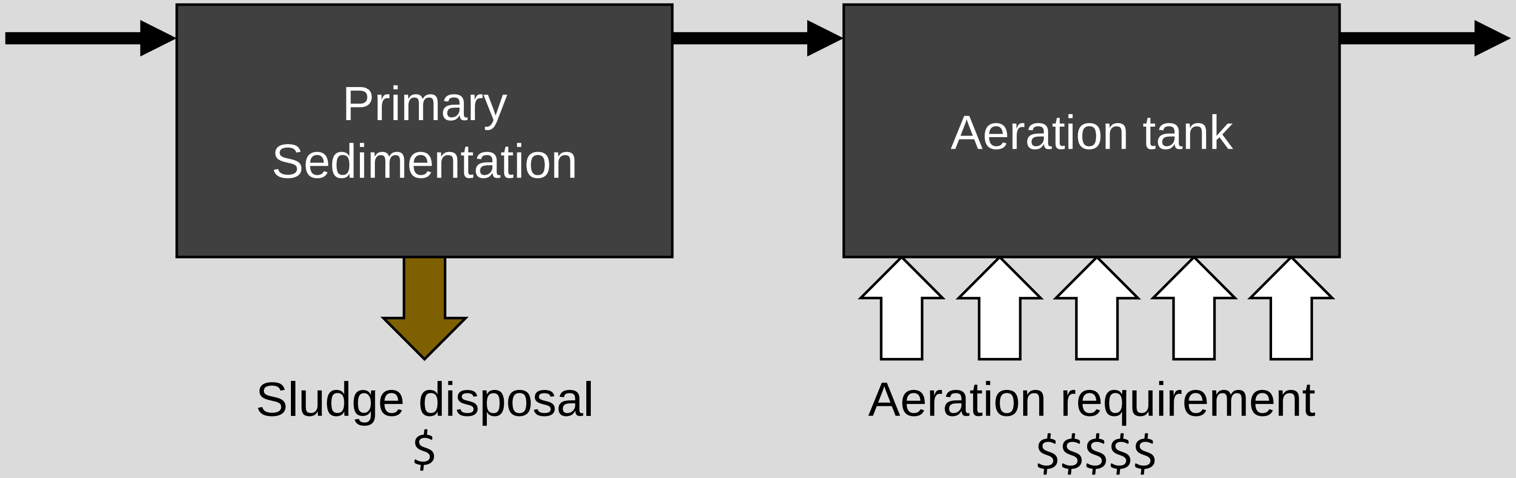
A separate experiment showed that adding Al and Fe reduces COD in wastewater



Adding AMD to a WWTP can reduce aeration requirements, but will require additional sludge disposal

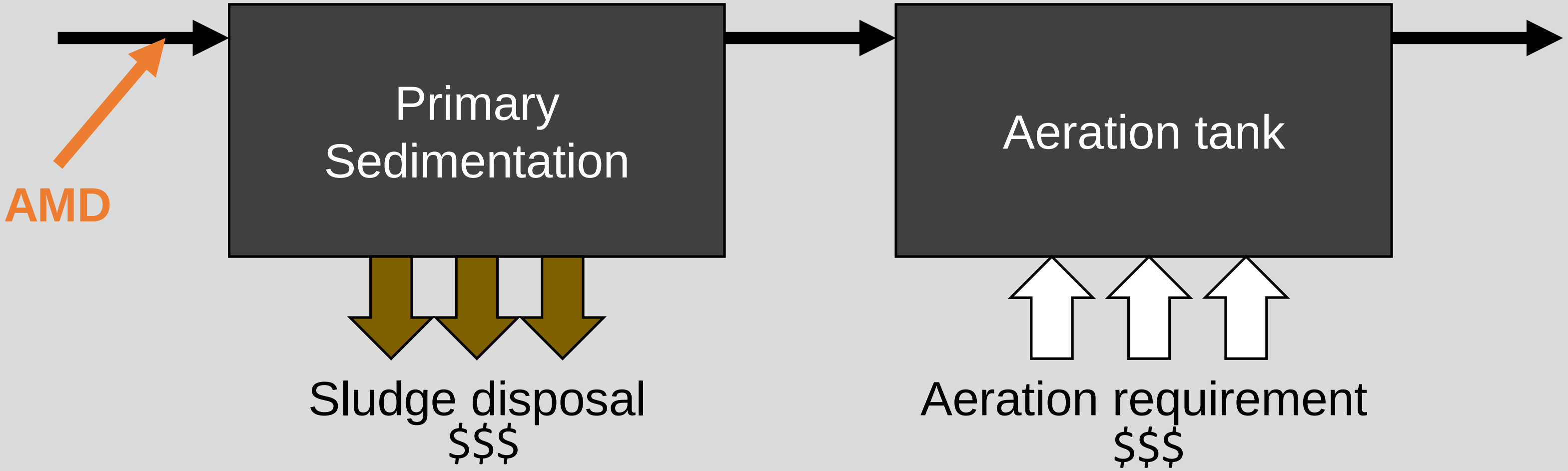
Energy requirements for a WWTP:

- ~50% for aeration
- ~10% for sludge pumping



Changes from adding AMD:

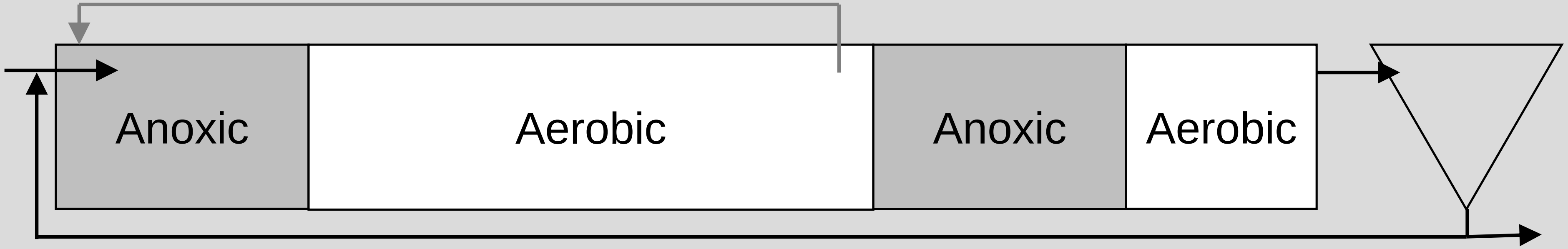
- **Increased sludge generation** in primary clarifier (biosolids vs landfill)
- **Reduced aeration requirement** from BOD being removed in clarifier by sweep coagulation



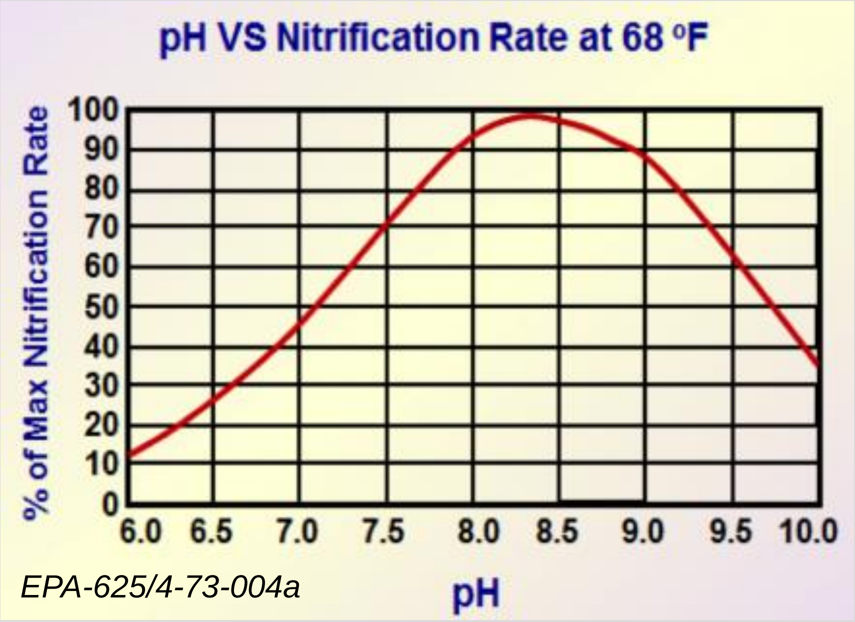
Further work to determine how nutrient removal is affected by adding AMD is still required

- Determine rates of phosphate removal in primary clarifier depending on types of metals and concentrations
  - Remove the need for complex systems designed for phosphate removal?

4-stage Bardenpho WWTP design



- Analyze the nitrifying capabilities of WW mixed with AMD.
  - Nitrifying bacteria are very sensitive to pH
  - Rates of ammonia oxidation drop-off significantly at pH < 7.2
  - May require sophisticated monitoring equipment to dose alkalinity in the influent to ensure that nitrogen removal remains consistent



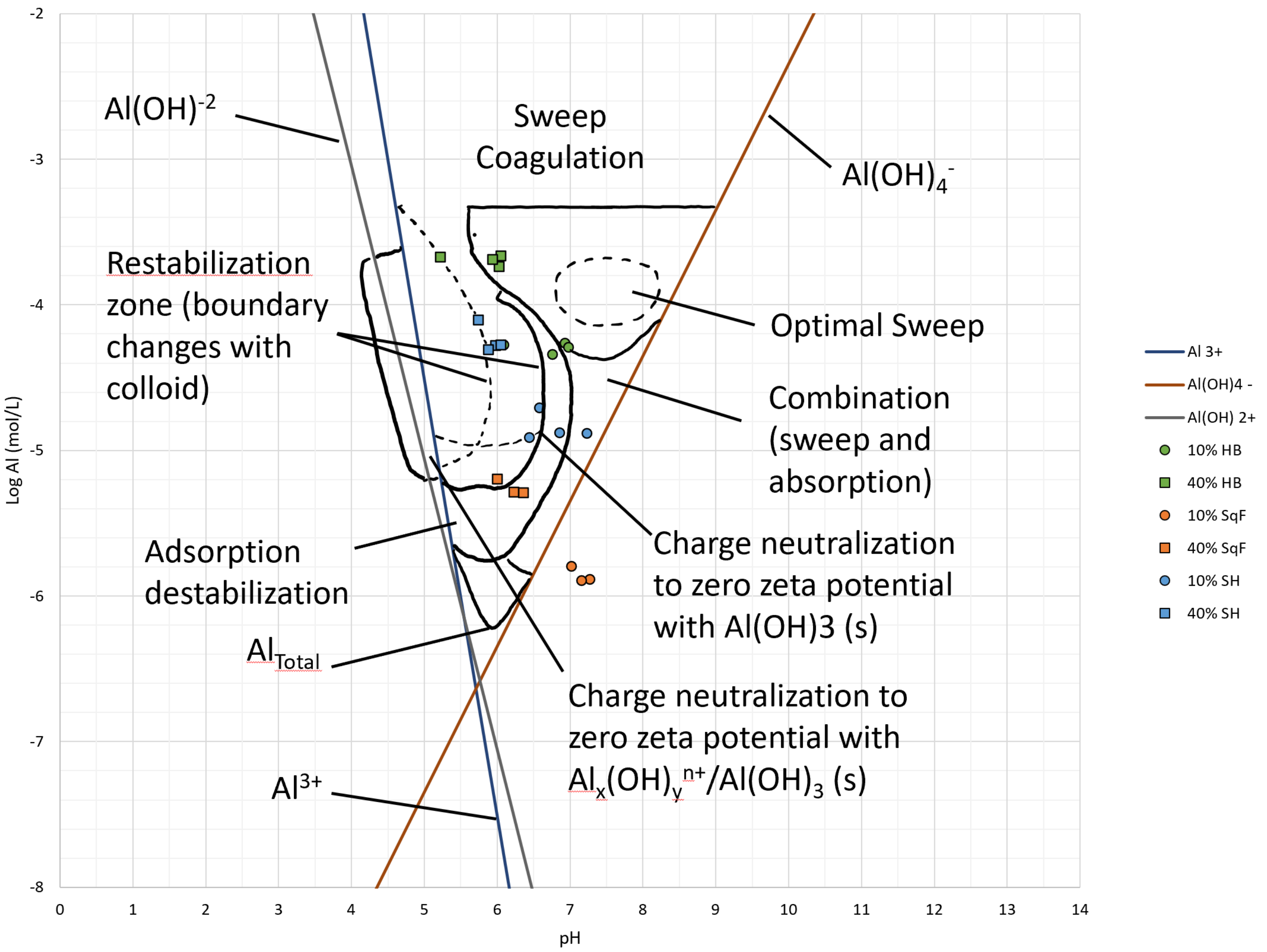
EPA-625/4-73-004a

Thank you!

Questions?

My email: ttasker@francis.edu

Special thanks to all the SFU undergraduate students who also assisted with lab experiments : Vittoria Larosa, Matt Berzonsky, Nicole Himes, Henry Warner



Al(OH)-2
Sweep
Coagulation
Al(OH)4-
Restabilization
zone (boundary
changes with
colloid)
Optimal Sweep
Combination
(sweep and
absorption)
Charge neutralization
to zero zeta potential
with Al(OH)3 (s)
Adsorption
destabilization
AlTotal
Charge neutralization to
zero zeta potential with
Alx(OH)yn+/Al(OH)3 (s)
Al3+
Log Al (mol/L)
pH
-2
-3
-4
-5
-6
-7
-8
0
1
2
3
4
5
6
7
8
9
10
11
12
13
14
Al 3+
Al(OH)4 -
Al(OH) 2+
10% HB
40% HB
10% SqF
40% SqF
10% SH
40% SH