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The Characterization and Treatment of Wastewater from Michigan's Meat Processing Facilities

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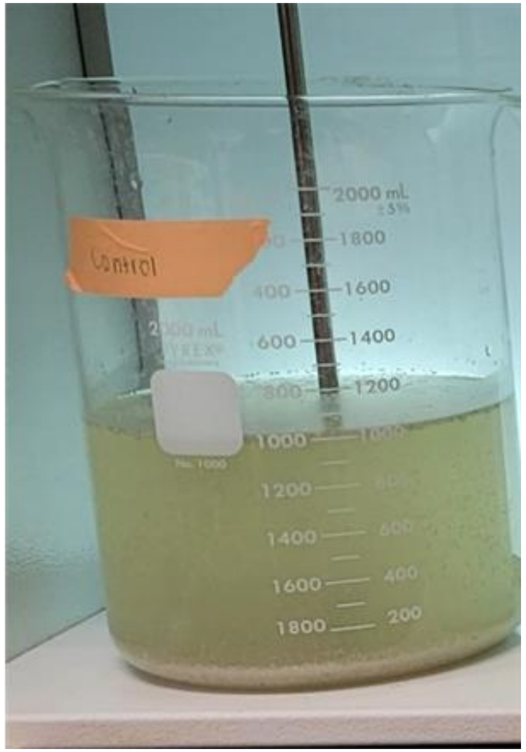
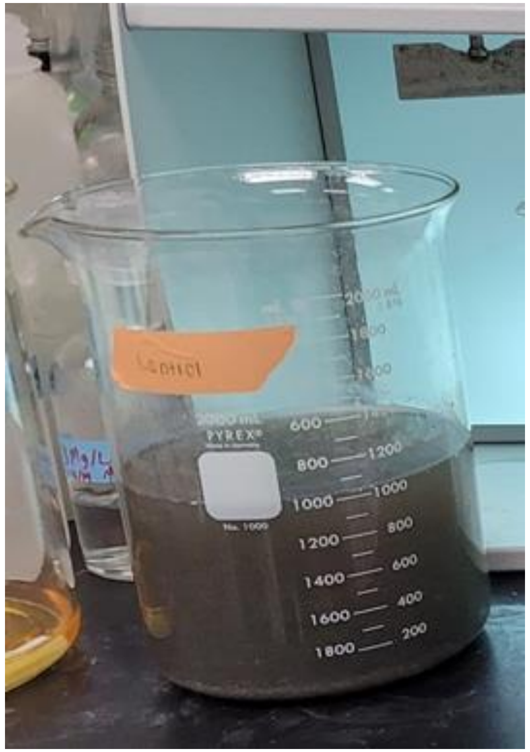
Motivation

- Michigan Department of Environment, Great Lakes, and Energy (EGLE) requires groundwater discharge permit
- Applicable for low-flow food processors that are not served by a centralized wastewater treatment plant
- Insufficient data regarding meat processing wastewater content
- Livestock industry seeks to grow in near future
- Evaluating existing technology will help future processors and those facing issues

Project Goals

- Survey and select representative processors and characterize facilities
- Design a sampling plan for selected facilities
- Characterize water leaving facilities
  - Wastewater characteristics
  - Variability
  - Treatment potential of units
- Determine effective sampling methods
- Determine effective methods for processors to meet permits





Permit

Michigan Groundwater Discharge General Permit GW 1530000, Meat Processing and Slaughterhouse Wastewater

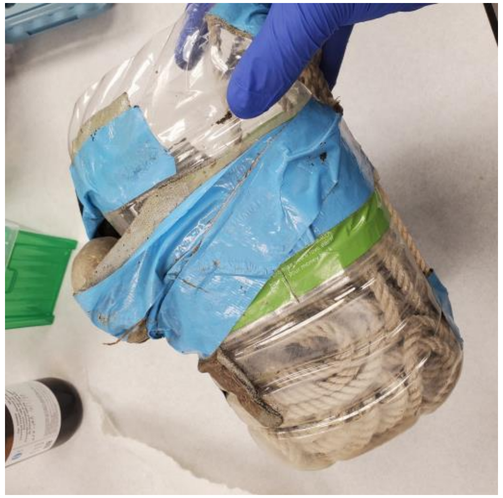
- Flow: ≤ 20,000 gallons/day
- Expiration: November 1, 2027
  - Treatment options:
    - A. Conventional onsite (series of grease traps and septic tanks) with subsurface discharge, no slaughterhouse wastewater
    - B. Enhanced treatment and subsurface discharge
    - C. Aerated or non-Aerated Lagoon discharging into a Rapid Infiltration Basin
    - D. Stabilization Lagoon discharging to Above Ground Slow-Rate Land Treatment
    - E. Holding Tank Discharging to an Above Ground Slow-Rate Land Treatment*
  - Limits are based on an individual processors certificate of coverage (COC) or are recorded, except for the following for some options.
    - BOD
    - Total Inorganic Nitrogen (TIN)
    - Nitrite

Parameter	A (Conventional w/ Subsurface Discharge, no slaughterhouse)	B (Enhanced w/ Subsurface Discharge)	C (Enhanced w/ Rapid Infiltration Basin Discharge)	D (Enhanced w/ Slow-Rate Land Treatment)***	E (Holding Tank w/ Slow-Rate Land Treatment)***	Unit
Flow (Daily)*	COC	COC	COC	COC & Report in/day and in/week**	COC & Report in/day and in/week**	GPD or in/week
Flow** (Annual)	COC	COC	COC	COC	COC	GPY
BOD_5	Report	COC	COC	COC & 50 lb/acre/day (mon. avg.)**	COC & 50 lb/acre/day (mon. av.)**	mg/L or lb/acre/day
TIN**	Report	10.0	10.0	COC	COC	mg/L
TKN	Report	Report	Report	Report	Report	mg/L
Nitrate – N	Report	Report	Report	Report	Report	mg/L
Nitrite -N	Report	1.0	1.0	1.0	1.0	mg/L
TP	Report	COC	COC	COC	COC	mg/L
Sodium	Report	Report	Report	Report	Report	mg/L
Chloride	Report	Report	Report	Report	Report	mg/L
TSS	Report	Report	Report	Report	Report	mg/L
pH	Report	Report	Report	Report	Report	S.U.
D.O.	Report	Report	Report	Report	Report	mg/L
Mg	Report	Report	Report	Report	Report	ug/L
Cr	Report	Report	Report	Report	Report	ug/L
Cu	Report	Report	Report	Report	Report	ug/L
Zn	Report	Report	Report	Report	Report	ug/L

*Depends on meter; **Calculation; ***Annual soil sampling (Bray P1, Na, pH, CEC, Nitrate); Sampling is monthly except for A; Grab Samples, except*

Site Selection and Sampling

- Six sites were selected for variety
- Team determined best sample collection locations
  - Start of system
  - Key units
  - End of system
- Tools created for sampling
- Six sampling visits
  - Summer: 4 events (July-August)
  - Fall: 2 events (October-November)
  - Include seasonal variability



Site Details

- Site A
  - Processes and smokes meat; no slaughter
  - Comingles waste and filters septic tank effluent
  - Two lagoons - site operator determines which one actively fills
  - Drainage occurred after summer sampling; last summer sample assumed discharge value
- Site B
  - Processes and slaughters
  - Comingles waste and filters septic tank effluent
  - Lagoon aeration began partway through sampling period
  - Lagoon drainage occurred in winter, average of two fall samples assumed discharge value
- Site C
  - Processes, slaughters, and smokes meat
  - Comingles waste and filters septic tank effluent
  - Lagoon pumped over a 5-day period that intersects with fall collections, average of two fall samples assumed discharge value

Site Details Continued

- Site D
  - Processes, slaughters, and smokes meat
  - Comingles waste
  - Access to sample processing and slaughter wastewater separately
  - Fall sample collected during lagoon drainage; assumed discharge value
- Site E
  - Processes, slaughters, and smokes meat
  - Aerated lagoon
  - Lagoon consistently drained in summer months; average of summer values is assumed as discharge values
- Site F
  - Processes meat; no slaughter
  - Comingles waste
  - Two lagoons in series, final lagoon aerated
  - Water captured in the loading bay mixes with septic tank water
  - This site practices infiltration instead of land application, no separate discharge values

Methods

- Three methods to obtain values
  - HACH Kits
  - Commercial Lab
  - Calculated – Inorganic N and Organic N
- Visual Observations Recorded
- Statistical Analysis
  - Slaughter v. Processing
  - Smoking v. No Smoking
  - Comingling v. No Comingling
  - Filter vs. No Filter
  - Each location compared to the other

Parameter	Method
Total Nitrogen (mg/L-N)	HACH 10208
Organic Nitrogen (mg/L-N)	Calculated
Nitrate(mg/L-N)	40 CFR 141, HACH 10206
Ammonia (mg/L-N)	EPA 350.1,351.1,351.2, HACH 10205
TKN (mg/L-N)	4500-N(Org) C. Semi-Micro-Kjeldahl
Inorganic Nitrogen (mg/L-N)	Calculated
Nitrite (mg/L-N)	HACH 10207
Phosphorus (mg/L-P)	EPA365.1, 365.3, HACH 8190
BOD_5 (mg/L)	SM 5210 B
COD (mg/L)	E410.4
TSS (mg/L)	EPA 160.2
pH	HACH Lange 50 50 T Probe
Hardness (mg/L)	SM 2340 C
Alkalinity (mg/L-$CaCO_3$)	SM 2320 B
FOG (mg/L)	E1664A
Calcium (mg/L)	E200.8
Sodium (mg/L)	E200.8
Copper (mg/L)	E200.8
Manganese (mg/L)	E200.8
Chloride (mg/L)	E200.8
Zinc (mg/L)	E200.8

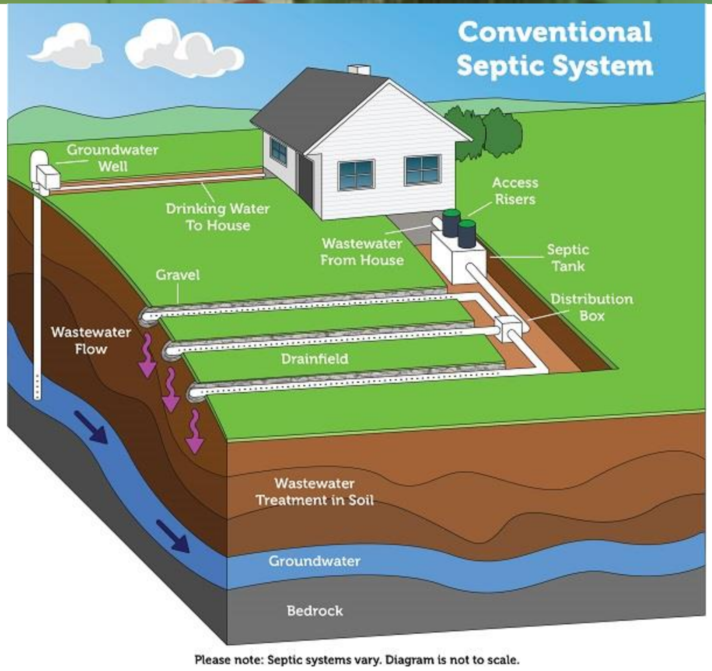
Sample Table: Total Nitrogen

Parameter (mg/L-N)	Facility						
	A Co,F, Sm	**B** Ae*, Co*, F,S	**C** Co,F,S,Sm	**D-Proc** Co,Sm	**D-Slau** Co,S,Sm	**E** Ae,S	**F** Ae,Co
Total N Inf	254[c]	626[b]	1064[a]	116[c]	370[bc]	133[c]	71.7[c]
Total N Lag	89.3[c]	110[c]	484[a]	229[b]		59.8[c]	80.2[c]
Total N Decrease	65%	63%	54%	26%		55%	-15%
Total N Discharge	20.0	101	489	264		57.9	80.2

[a-c] Within a row, values without a common superscript differ (P < 0.05) significantly.
Ae = Aerated Lagoon, Co = Comingled, F= Filter, S = Slaughterhouse, Sm = Smoking
*Site B added aeration and comingling during the sample collection period

Impact of Facility Characteristics

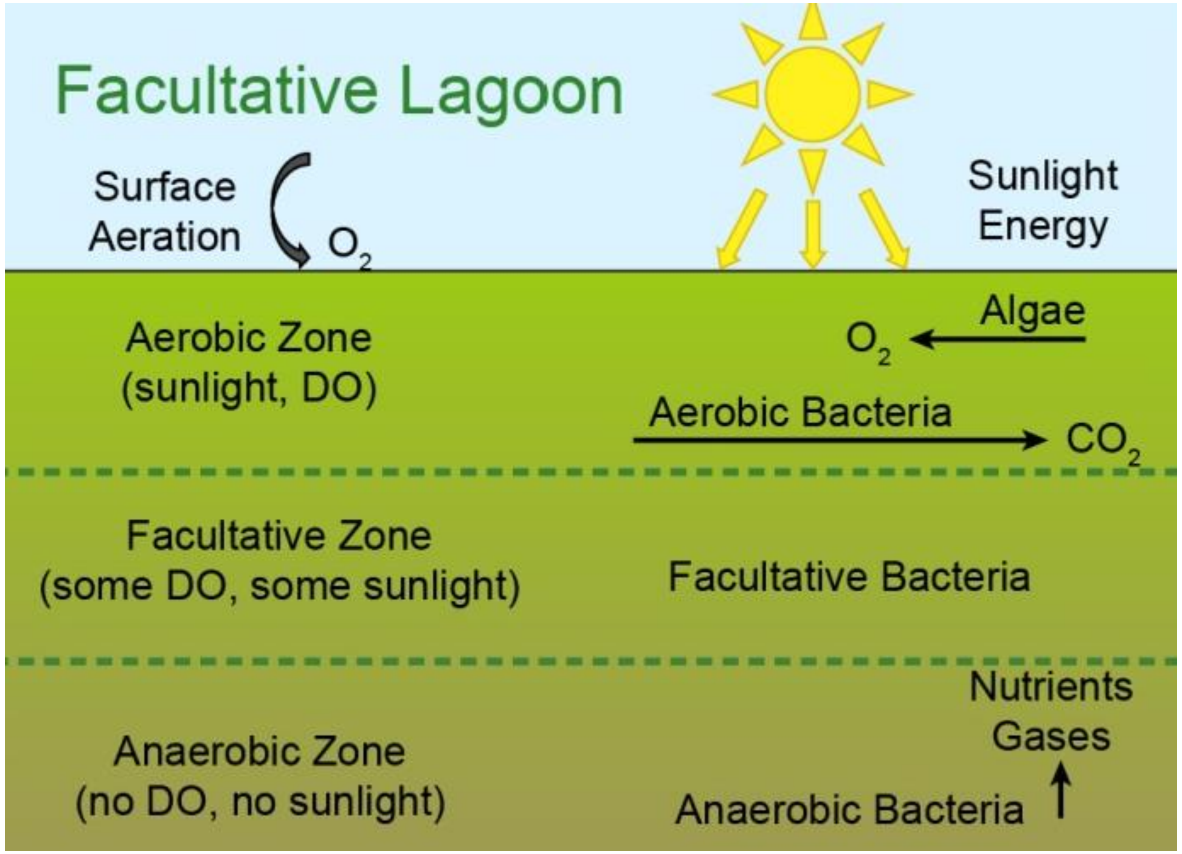
- Slaughter and Processing vs. Processing Only
  - 3.4x higher Total N
  - 1.9x higher Phosphorus
  - 1.8x higher BOD
  - 2.5x higher COD
- Meat Smoking vs. Non-Smoking
  - 1.9x higher NO_3
  - 2.2x higher Phosphorus
  - 2.2x higher BOD
  - 2.4x higher COD
- Comingle Human Wastewater vs. Separation
  - 1.6x higher COD
  - Comingling appears to have minor impact on water leaving facility



Impact of Facility Characteristics

- Effect of Septic Tank Filter
  - 97% less copper
  - 55% less manganese
  - 90% less zinc
  - 52% reduction in BOD
  - 69% reduction in COD
  - 98% reduction in FOG

- Aerated lagoon vs. No Aeration
  - 67% reduction in total N
  - 71% reduction in TKN
  - 83% reduction in BOD
  - 75% reduction in COD



Conclusions of Characterization

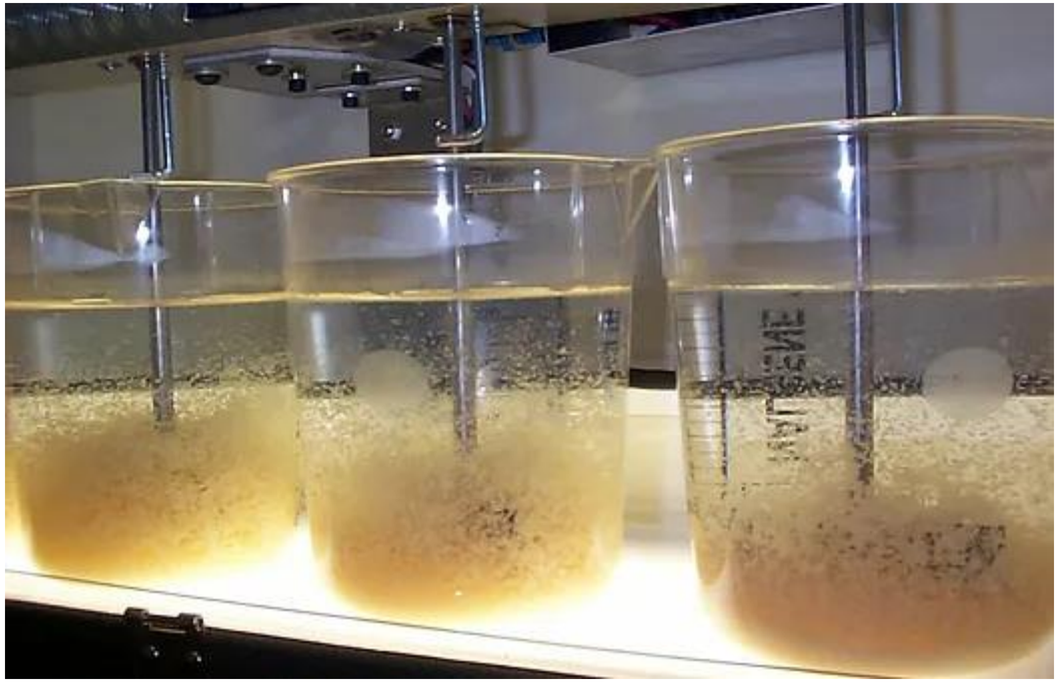
- Sampling required for permit compliance should be done as close to time of discharge as possible, when applicable
- Pre-treatment such as coagulation/flocculation will help processors meet new permit
- Additional samples from key locations improve site understanding

Conclusions of Characterization

- Slaughtering led to increased nutrients, BOD, and COD
- Filters had major impact on BOD, COD, and metals in the system
- Comingling of human waste had minimal effects on wastewater
- Smoking sites demonstrated increased nitrate, phosphorus, BOD and COD
- Aeration improved the removal of nitrogen, reduced BOD and COD
- All but one facility studied demonstrated a sizeable decrease in total N

Next Steps: Coagulation/Flocculation

- Premise: a substantial amount of pollutants can be removed as solids
- What do they do?
  - Cause compounds in wastewater to bind together
  - Bound compounds become heavy enough to settle
  - Works best in water with high turbidity and alkalinity[1]
- Where would coagulants be used?
  - Treatment systems worked with all contain a biological treatment lagoon
  - Use as a pre-treatment, lagoons will polish the water



Coagulants

- What are coagulants?[1]
  - Charged compounds
  - Typically nontoxic in working doses
- Inorganic
  - Conventional treatment method
  - Lower cost
  - Wider optimal pH range
  - Greater impact on pH of water
- Organic
  - Reduced risk of harmful chemical residue[2]
  - More environmentally friendly options

40% Ferric Chloride Solution

Coagulation Project Goals

- Determine if coagulation and flocculation is economically feasible and practically applicable for small volume meat processors.
- Figure out which coagulant(s) are best for processors
  - Which is the most cost effective?
  - Which operates best in non-optimized application?
  - Will it affect plants after land application?

Potential Setup

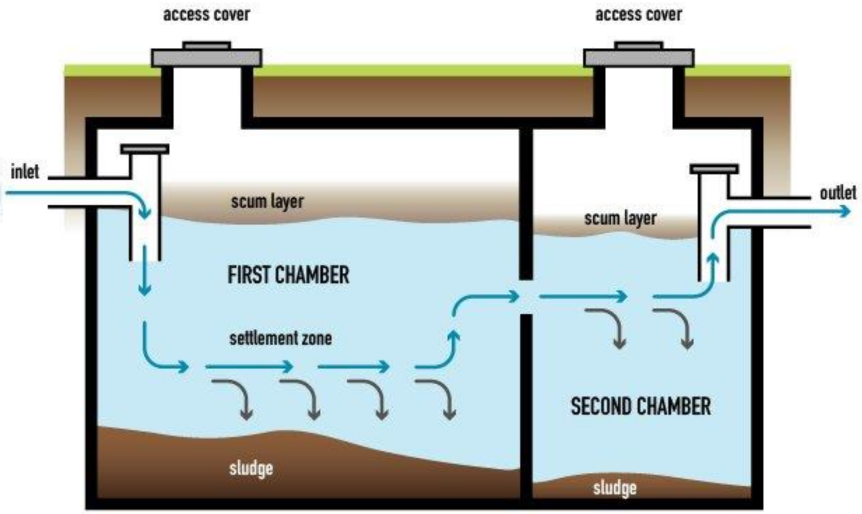
- Modify existing septic systems
- Coagulant mixed with water leaving facility
  - Easier to connect to existing electrical
  - Chemical can be replenished close to facility
- Static mixers added to inlet

Processing Facility

Coagulant added

Static Mixer

Treatment System

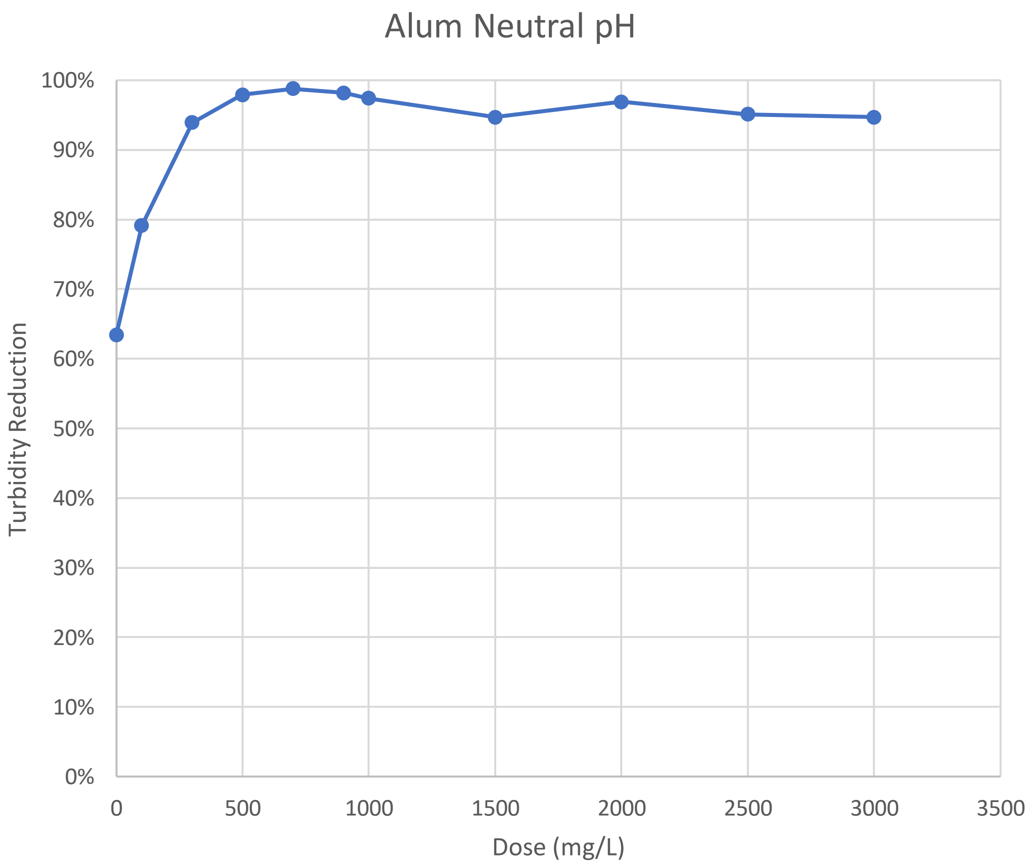


Coagulation/Flocculation – Methods

- Jar testing
  - Add 1L of water per beaker
  - Add Coagulant: Mix 40 rpm for 30 seconds
  - RapidMix:125 rpm for 60 seconds
  - Slow Mix: 40 rpm for 120 seconds
  - Allow 10+ minutes for settling (simulates flocculation)
- Wastewater from a processor was utilized
- Turbidity and other wastewater characteristics tested

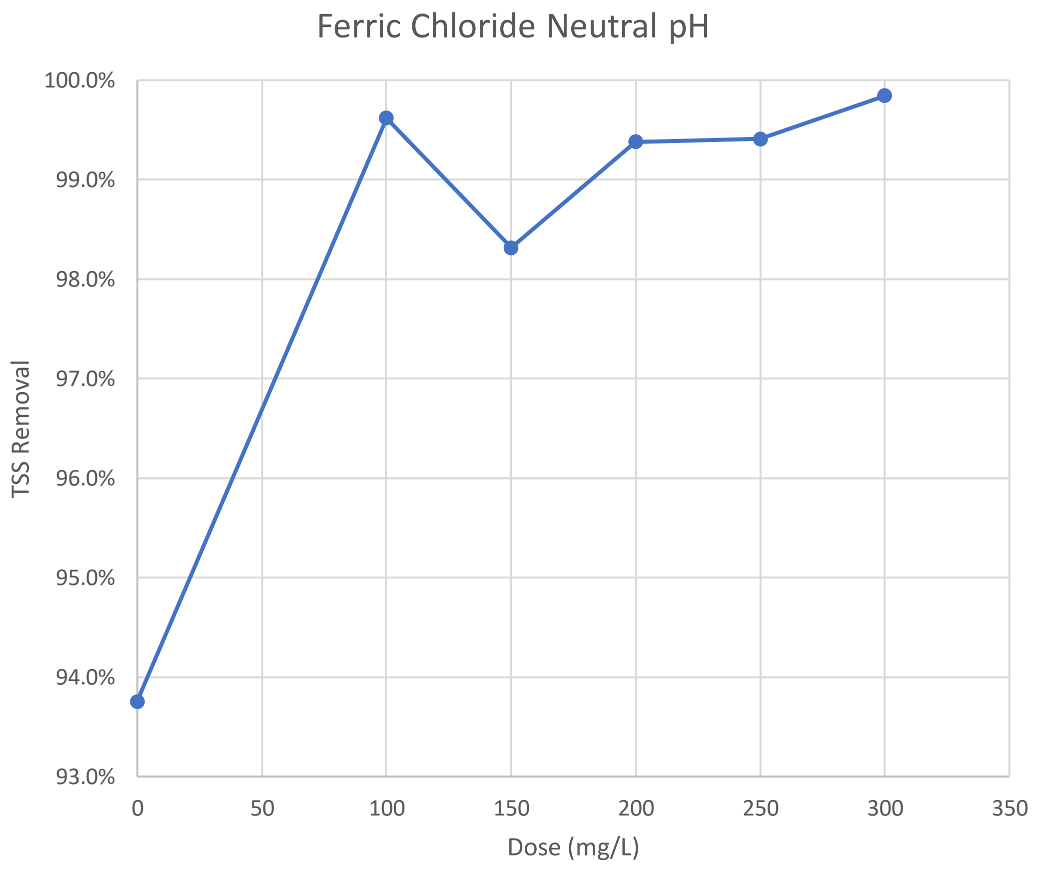
Alum Dosing Test

- Unaltered water, 6-7 pH
- Alum is very effective
- Typically sold in 48-50% solutions in bulk
- Very commonly used for drinking water



Ferric Chloride Dosing Test

- Turbidity of starting water too high to read
- Total Suspended Solids (TSS) measurements done
- Final Control TSS is 575, treated was between 25 and 135 mg/L



What is Chitosan?

- Organic compound made from chitin
- Formulated from crab shells
- Comes in 2%, 10%, or hybrid products with coagulant aids
- Also sees use in biomedical and agricultural industries

https://zenonco.io/cancer/chitosan/

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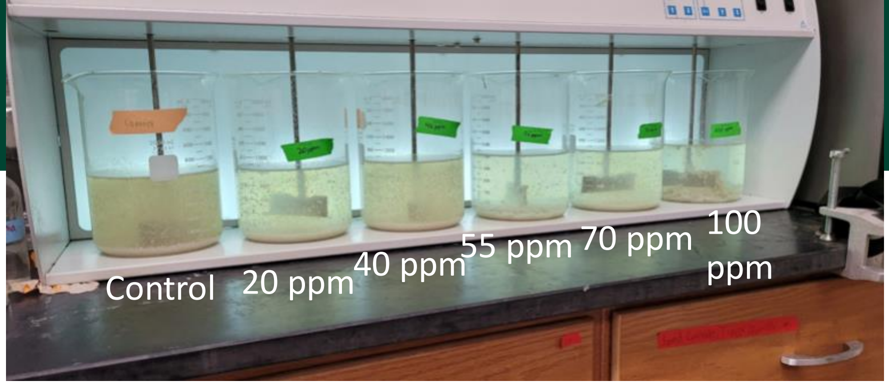
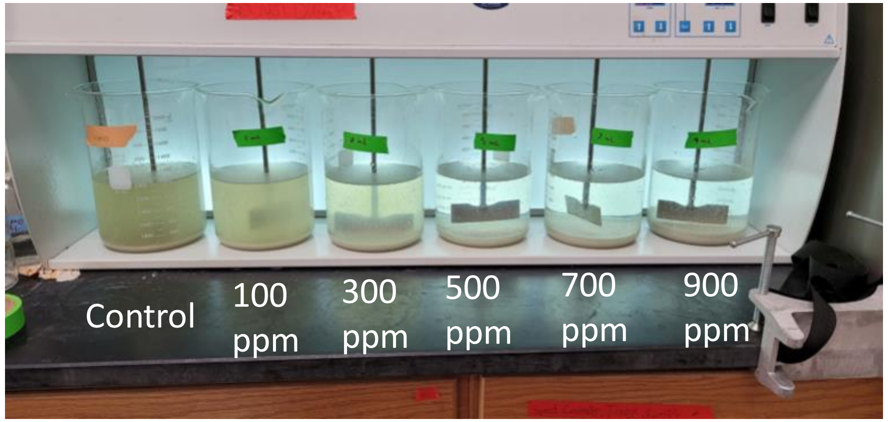
Coagulant Aided Flocculation

- Chitosan Testing
  - 50-60% of COD removed
  - 30-50% of TN removed
  - 10-15% of Phosphorus removed

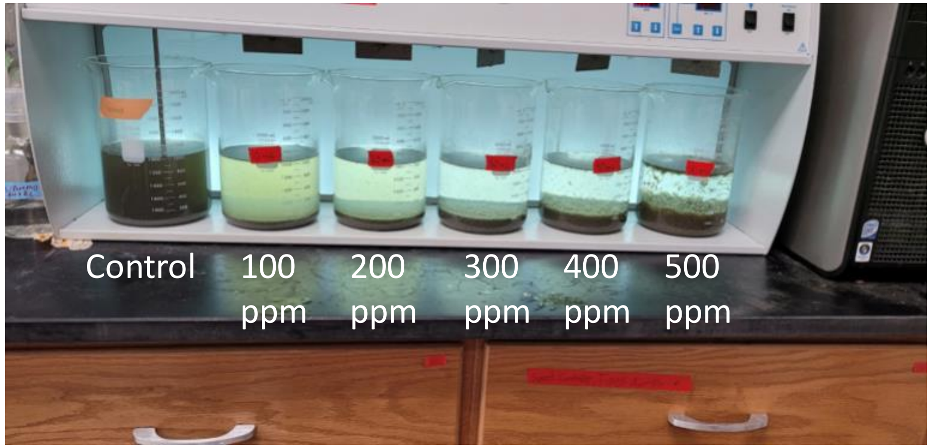
- Turbidity Reduction to 6 NTU
  - Drinking water is 1-5 NTU
  - Alum: 700 ppm
  - Ferric Chloride: 300 ppm
  - Chitosan TCH 8 (Hybrid Product): 45 ppm



Chitosan 2% with pH 6 (Altered)



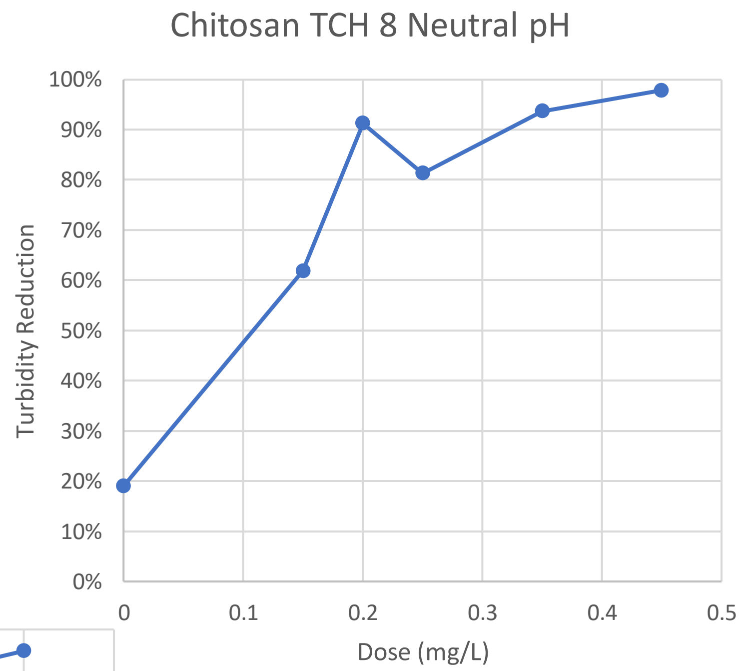
Alum with pH 6.7

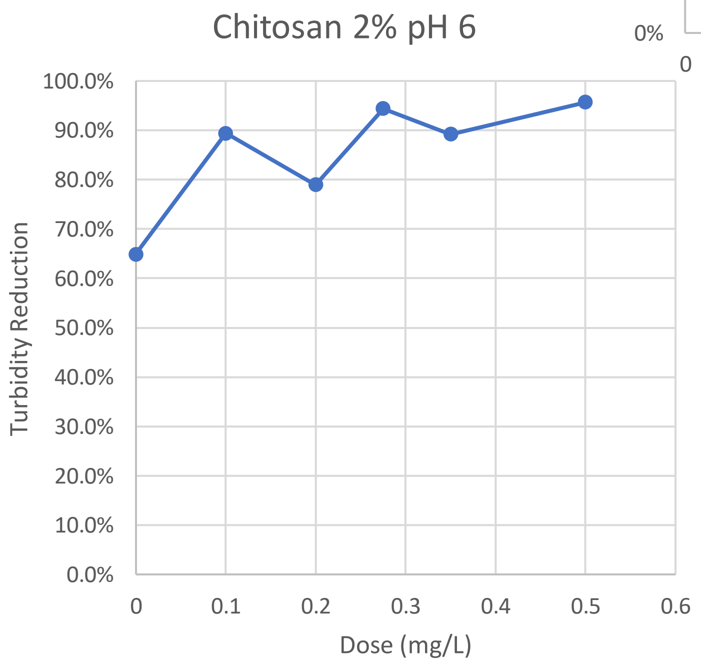


Ferric Chloride with pH 7.5

Chitosan Dosing

- Non-Hybrid cost prohibitive dosing required above 6.5 pH
- pH reduction necessary if non-hybrid product used
- Hybrid product worked in neutral pH range





Next Steps

- Test all coagulants on slaughterhouse water
- Determine possible impacts of coagulants when land application occurs
- Research other inorganic and organic coagulants
- Develop a cost-effective method of adding coagulation and flocculation to sites
- Look into other technologies such as direct filtration

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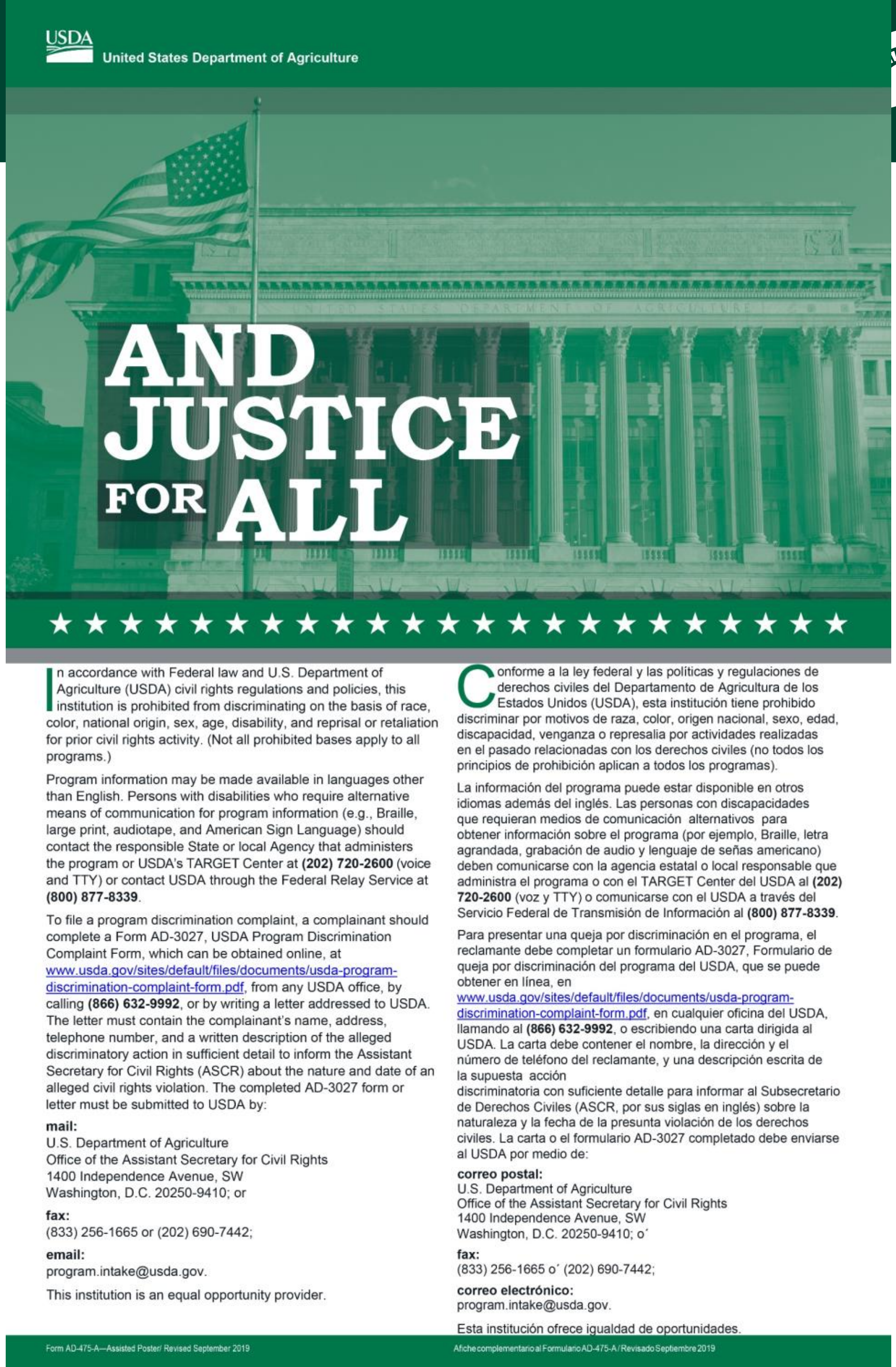

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