Performance Evaluation of the Hydrotech Belt Filter in Intensive Recirculating Aquaculture Systems

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Introduction

Problem: TSS in Aquaculture Discharged Effluent

- EPA: Best Management Practices (BMP)
- NPDES permits: state or regional NPDES permits
- Concentration of suspended solids
- Reduce quantity of discharge water
- Minimize storage volume

Hydrotech Belt Filter (Water Management Technologies)

Belt Filter System, Hydrotech Model HBF537-1H

Influent: 600 – 1400 mg/L
Effluent: 15% Solids

Objectives

- Summary of the current waste treatment systems
- Coagulation/Flocculation
- Performance evaluation of Hydrotech Belt filter

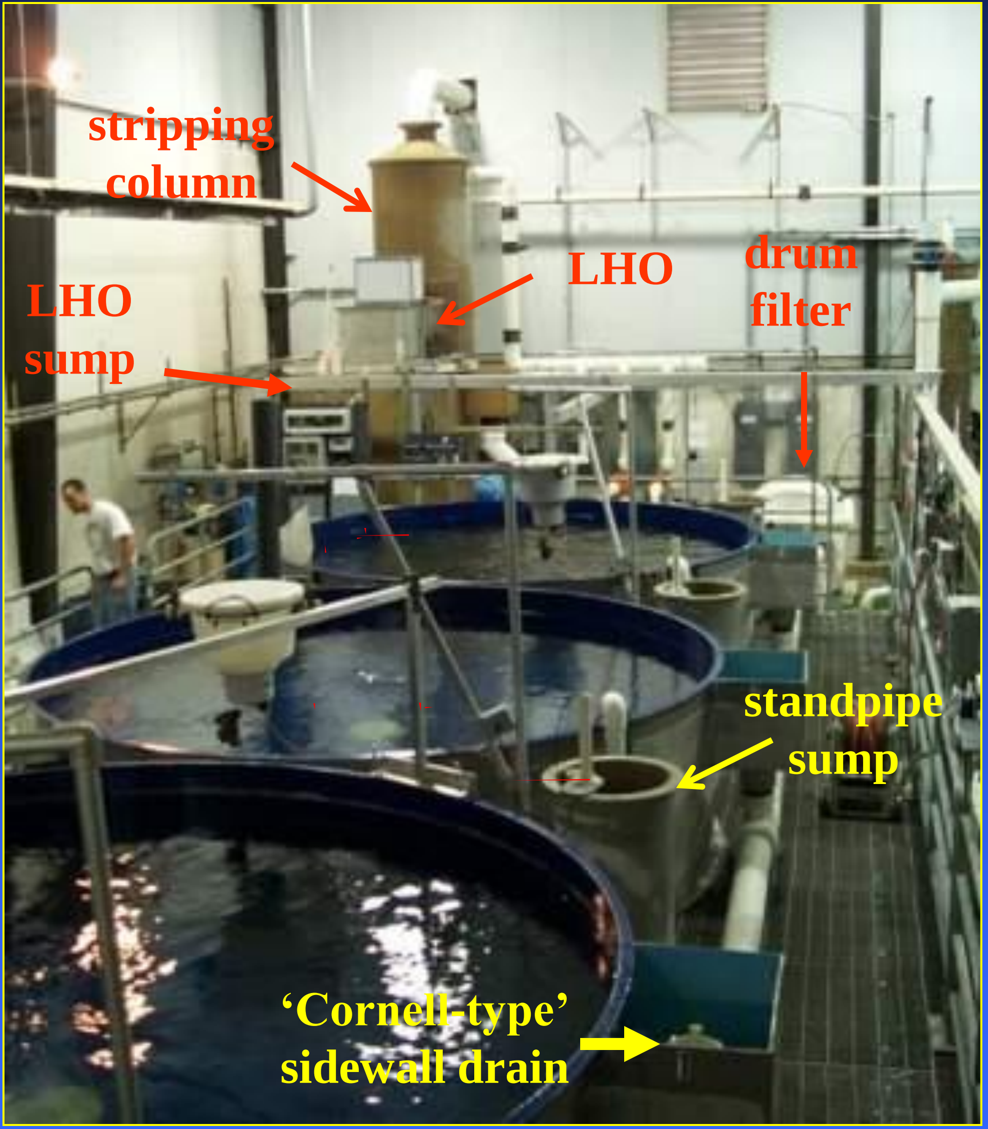
Freshwater Institute Intensive Recirculating Aquaculture Production Systems

- Partial-Reuse Fingerling System
- Recirculating Growout System

Partial-Reuse Fingerling System

Partial-reuse system:

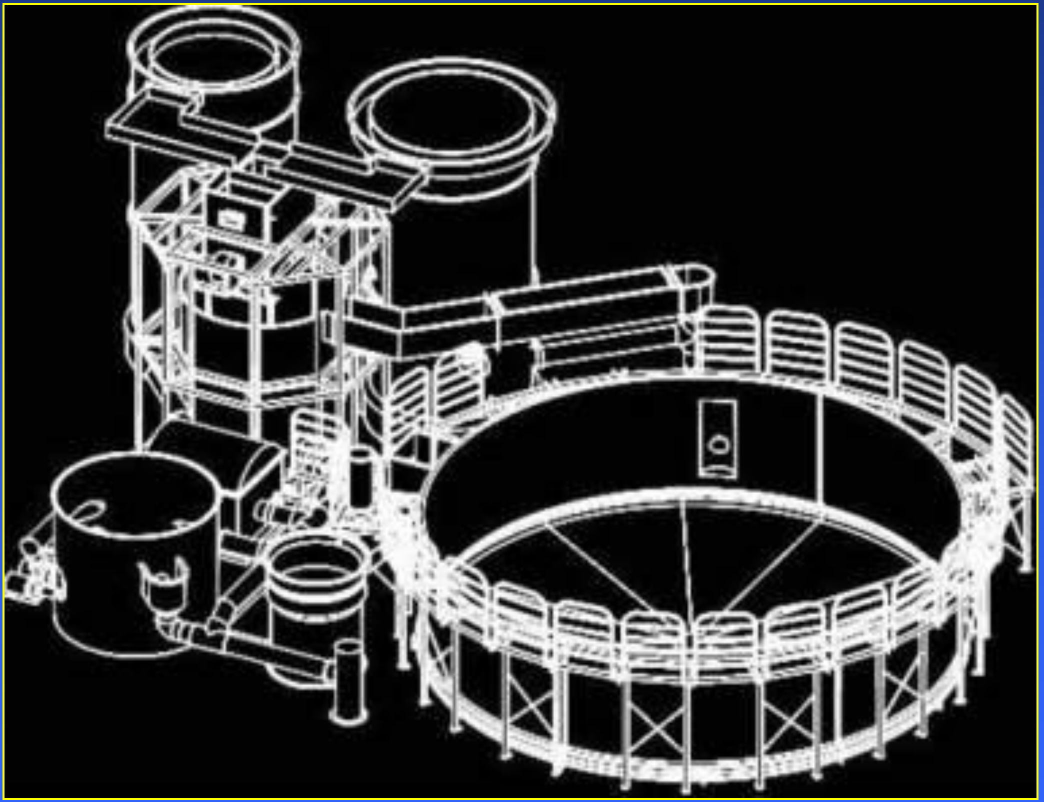
- NH_3-N controlled by pH
- pH controlled by CO_2
- 1500 lpm recirc
- bottom drain flow is discharged from system
- 12-15% of water flow
- sidewall flow is reused after microscreen filtration
- 45-50 kg feed/day



Recirculating Growout System

Fully-recirculating system

- 4 - 8% make-up rate on a flow basis (0.5-1.0 day HRT)
- 4,800 lpm recir. water flow
- 150 m^3 culture volume
- 7% through bottom drain
- 93% through side drain
- 200 kg/day feed



(Courtesy of Marine Biotech Inc.)

Current Aquaculture Waste Management

Polishing Microscreen Filter
Model RFM 4848, Manufacturing, Ltd.

Backwash Water Sump

Current Aquaculture Waste Management

Current Aquaculture Waste Management

Pumping Settling Cones

Aerobic Lagoon

BOD In: 6 mg/L
BOD out 2 mg/L

Land Application / Composting

Waste Management – Discharge Parameters

Parameter		Mean
pH		7.43
Temp	(Deg. C)	19.4
Alkalinity	(mg/L)	292
Turbidity	(FTU)	Over range
TP	(mg/L - P)	77.8
RP	(mg/L - P)	12.3
TSS	(mg/L)	1015
TVS	(mg/L)	753
TN	(mg/L - N)	77.8
TAN	(mg/L - N)	14.8
NO_2	(mg/L - N)	0.43
NO_3	(mg/L - N)	38.8
$cBOD_5$	(mg/L)	548

Objectives

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Coagulation/Flocculation

Coagulation

Process of decreasing or neutralizing the electric charge on suspended particles

Flocculation

Process of bringing together the microfloc particles to form large agglomerations by the binding action of flocculants

Suspended Solids Removal

Alum in wastewater yields the following reaction:

$Al_2(SO_4)_3 \bullet 14\ H_2O + 3Ca(HCO_3)_2 \Leftrightarrow 3Ca\ SO_4 + 2Al(OH)_3 + 6CO_2 + 14H_2O$

Insoluble aluminum hydroxide is a gelatinous floc

Ferric Chloride in wastewater yield the following reaction:

$2FeCl_3 \bullet 6H_2O + 3Ca(HCO_3)_2 \Leftrightarrow 3CaCl_2 + 2Fe(OH)_3 + 6\ CO_2 + 12H_2O$

Insoluble ferric hydroxide is a gelatinous floc

Phosphorus Removal

Basic reaction:

$$Al^{+3} + H_nPO_4^{3-n} \Leftrightarrow AlPO_4 + nH^+$$

$$Fe^{+3} + H_nPO_4^{3-n} \Leftrightarrow FePO_4 + nH^+$$

- Simplest form of reaction, bench-scale test required to establish actual removal rate

Coagulation/Flocculation Aids

Advantages:

High Molecular Weight Long-chain Polymers

- lower dosages requirements
- reduced sludge production
- easier storage and mixing
- MW and charge densities optimized “designer” aids
- no pH adjustment required
- polymers bridge many smaller particles
- improved floc resistance to shear forces

Polymers

Process Efficiency depends on:

- polymer concentration
- polymer charge (anionic, cationic, and nonionic)
- polymer molecular weight and charge density
- raw wastewater characteristics

  (particle size, concentration, temperature, hardness, pH)
- physical parameters of the process

  (dosage, mixing energy, flocculation energy, duration)
- discharge water treatment levels required

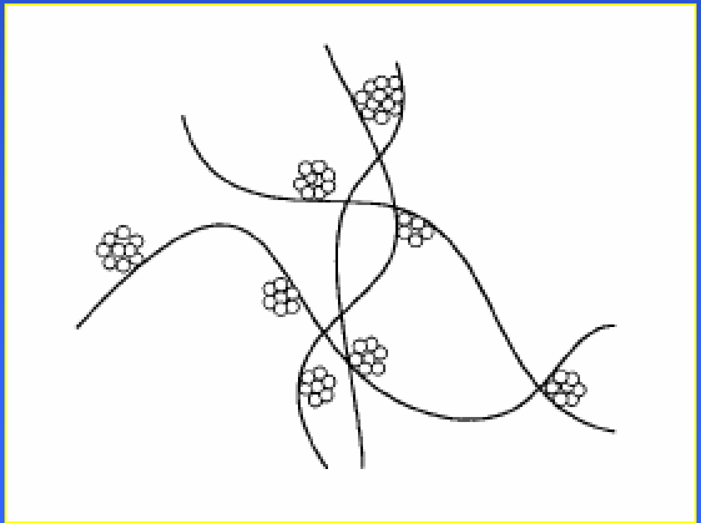
How Polymers Work

- charge neutralization (low molecular weight polymers)

  neutralize negative charge on particle

- bridging between particles (high molecular weight polymers)

  long loops and tail connect particles



Polymer Evaluation

Similitude Studies with Jar Tests

- Jar Tests of coagulant and flocculant aids
  - Effect of mixing speed, (velocity gradient)
  - Effect of flocculation speed
  - Effect of coagulant type and dosage
  - Effect of flocculant (polymer) type and dosage

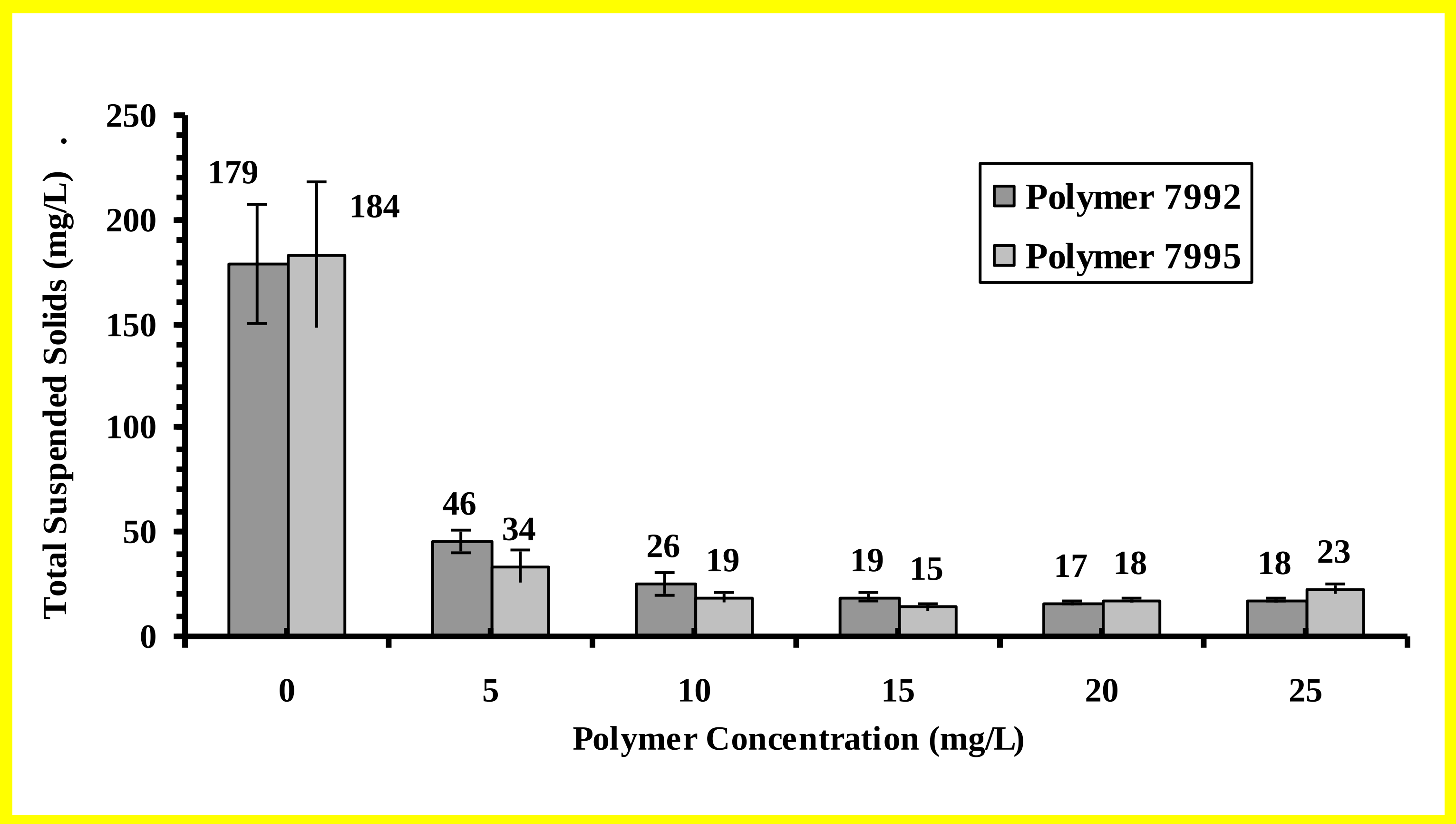
Jar Tests

Water Quality

- pH
- Turbidity
- RP (orthophosphate)
- Alkalinity
- TSS

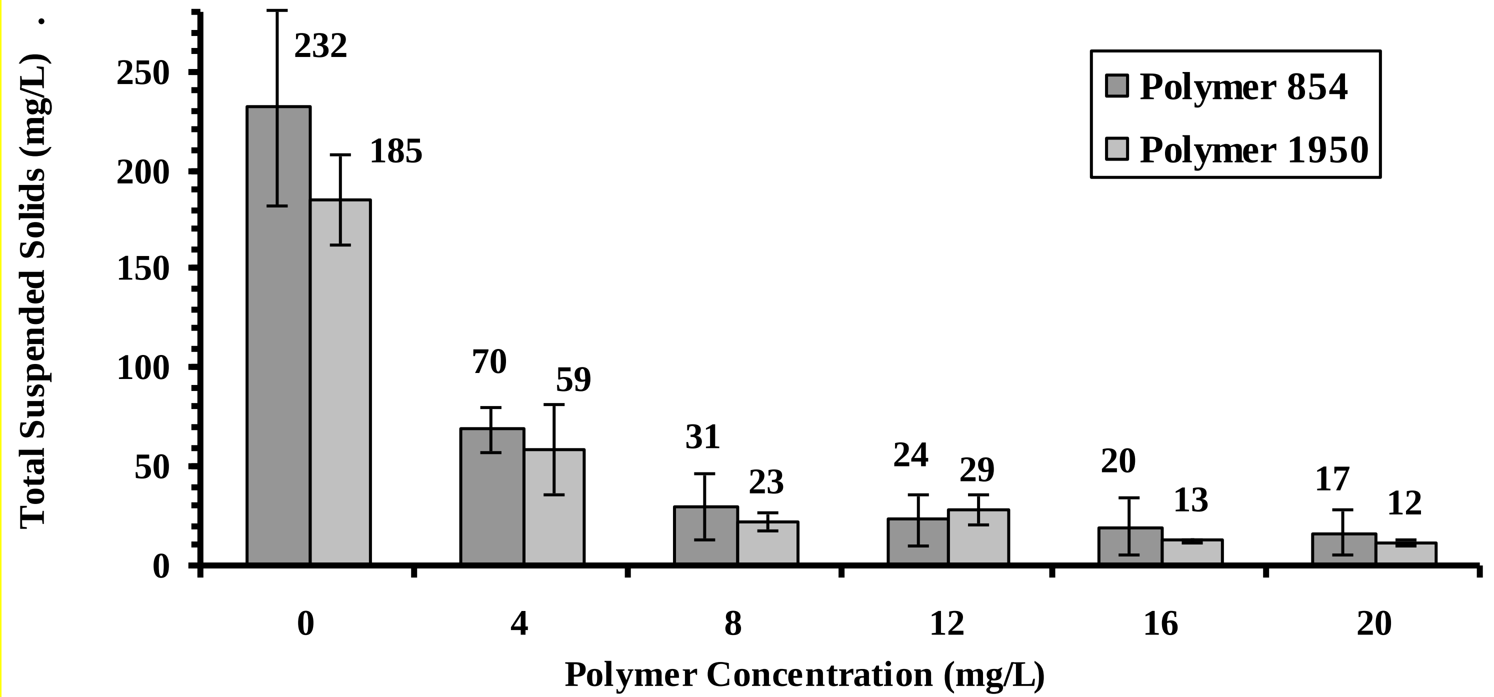
Phipps and Bird Six-Paddle Stirrer with Illuminated Base

Similitude Results



Total Suspended Solids removed using very high degree of cationic charge, very low Molecular Weight Polymers

Similitude Results



Total Suspended Solids removed using high degree of cationic charge, very high molecular weight Polymers

Objectives

- Summary of the current waste treatment systems
- Polymer Selection
- Performance evaluation of Hydrotech Belt filter

Hydrotech Belt Filter System

Hydrotech Belt Filter

Coagulation/Flocculation Tank

Hydrotech Belt Filter

Belt Filter

Hydrotech Belt Filter

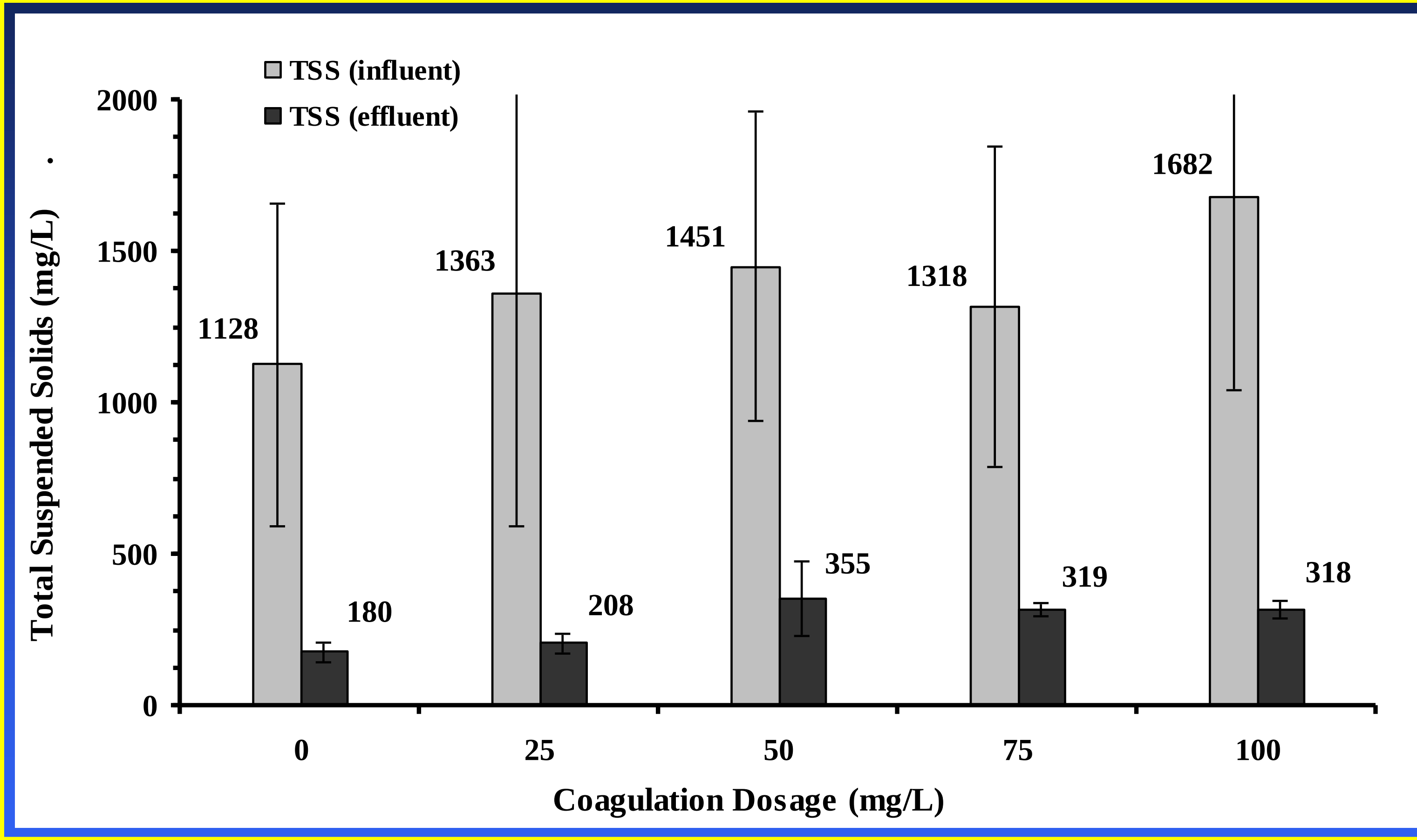
Objectives

- Summary of the current waste treatment systems
- Polymer Selection
- Performance evaluation of Hydrotech Belt filter
  - Alum as Coagulation Aid
  - **Polymer as Coagulation Aid**
  - **Alum and Polymer as Coagulation/Flocculation Aids**

Alum

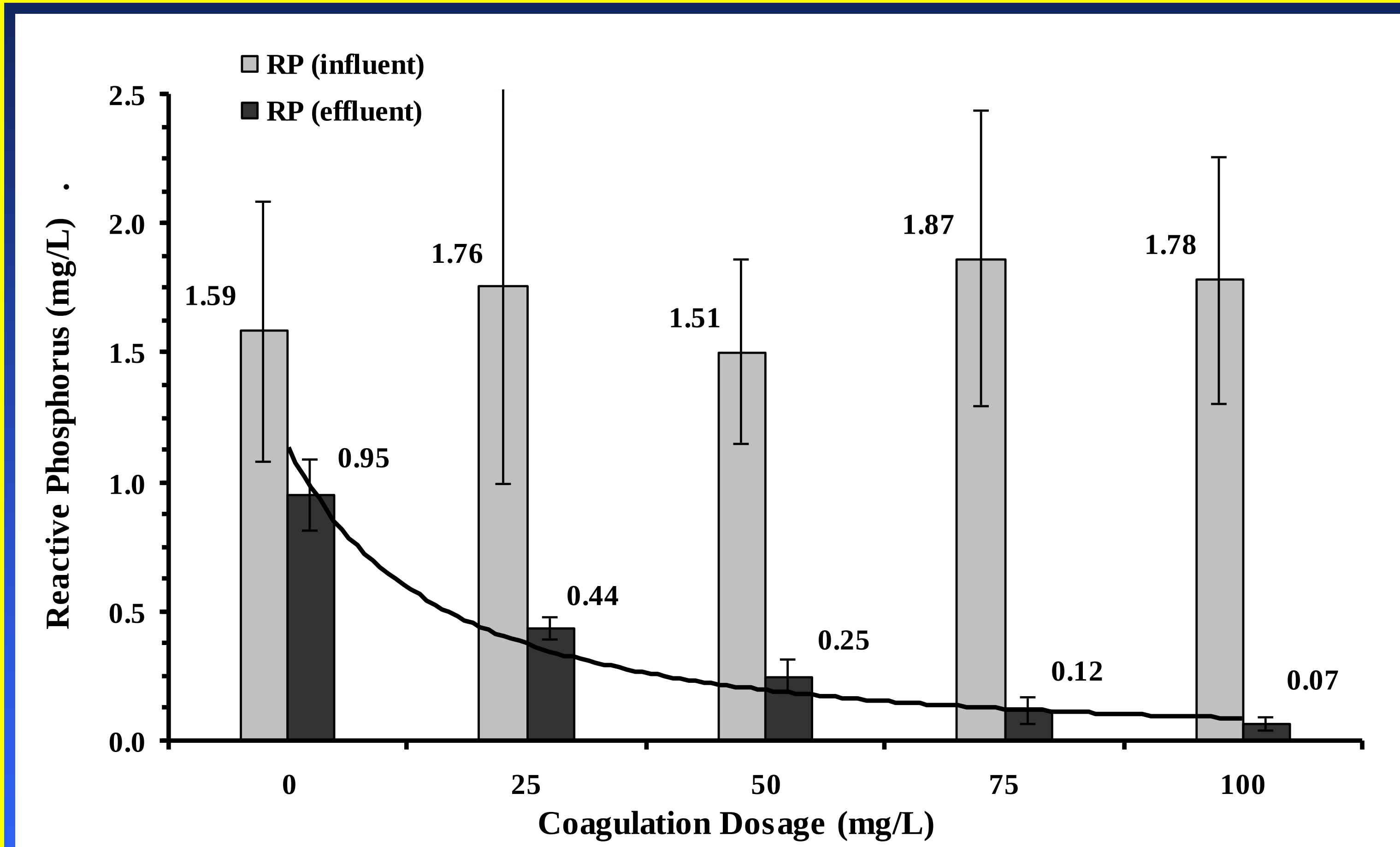
Alum Dosage		pH	Alkalinity (mg/L)	TSS (mg/L) Mean:	StDev:	RP (mg/L-P) Mean	StDev:
0 mg/L	Influent	7.37	286	1128	534	1.59	0.50
(11)	Effluent	7.39	287	180	33	0.95	0.14
	% Removal			**82%**		**38%**	
25 mg/L	Influent	7.32	303	1363	768	1.76	0.77
(7)	Effluent	7.33	302	208	34	0.44	0.04
	% Removal		1%	**83%**		**71%**	
50 mg/L	Influent	7.29	283	1451	509	1.51	0.36
(7)	Effluent	7.24	270	355	122	0.25	0.07
	% Removal		4%	**75%**		**82%**	
75 mg/L	Influent	7.29	292	1318	527	1.87	0.57
(7)	Effluent	7.19	274	319	21	0.12	0.05
	% Removal		6%	**72%**		**93%**	
100 mg/L	Influent	7.30	288	1682	635	1.78	0.48
(7)	Effluent	7.06	242	318	31	0.07	0.03
	% Removal		16%	**79%**		**96%**	

Hydrotech Belt Filter



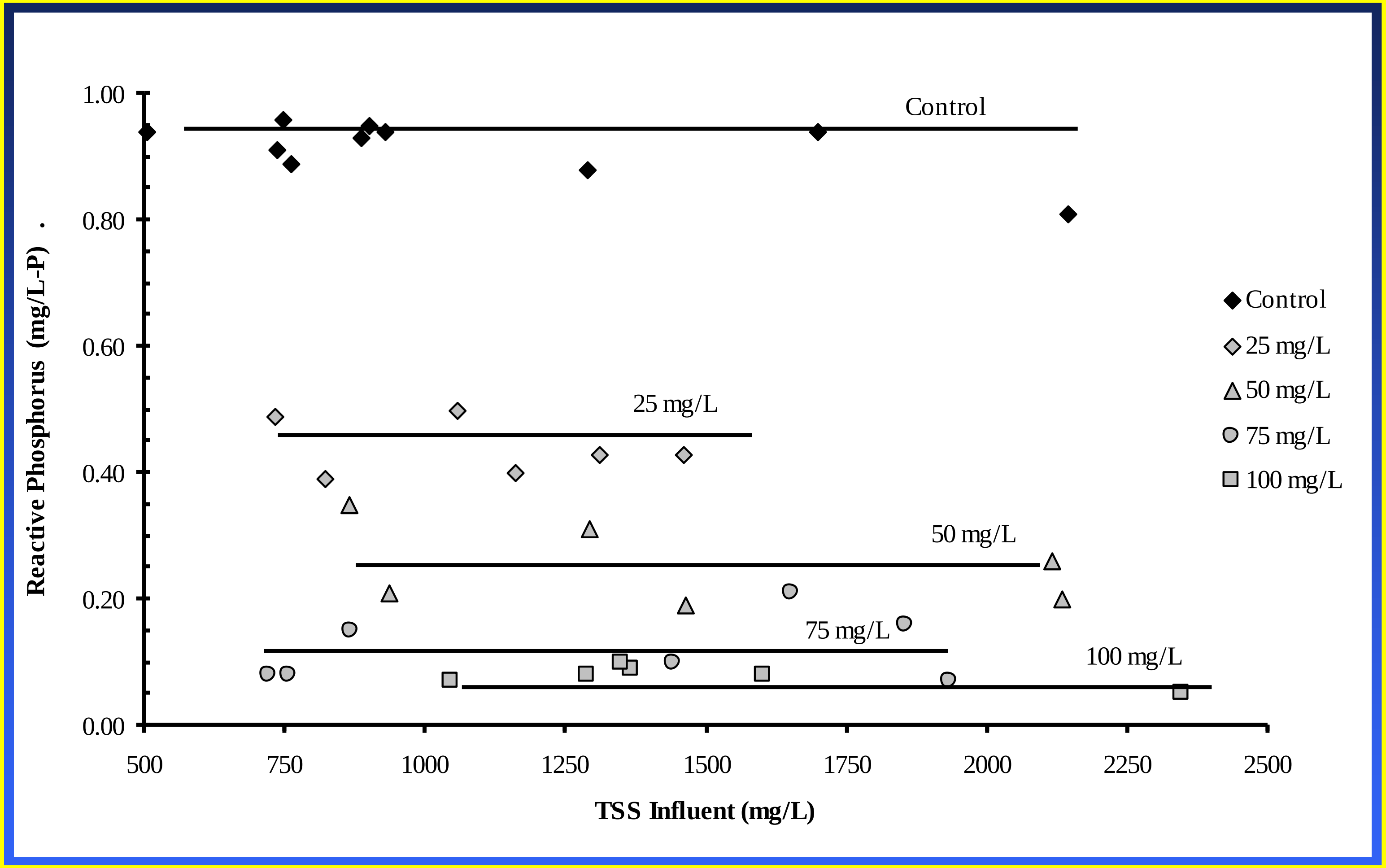
Total suspended solids for the influent from the microscreen backwash sump and effluent from the belt filter as a function of alum dosage (mg/L).

Hydrotech Belt Filter



Reactive phosphorus for the influent from the microscreen backwash sump and effluent from the belt filter as a function of alum dosage (mg/L).

Hydrotech Belt Filter



Reactive phosphorus for the effluent from the belt filter as a function of total suspended solids of the influent (mg/L).

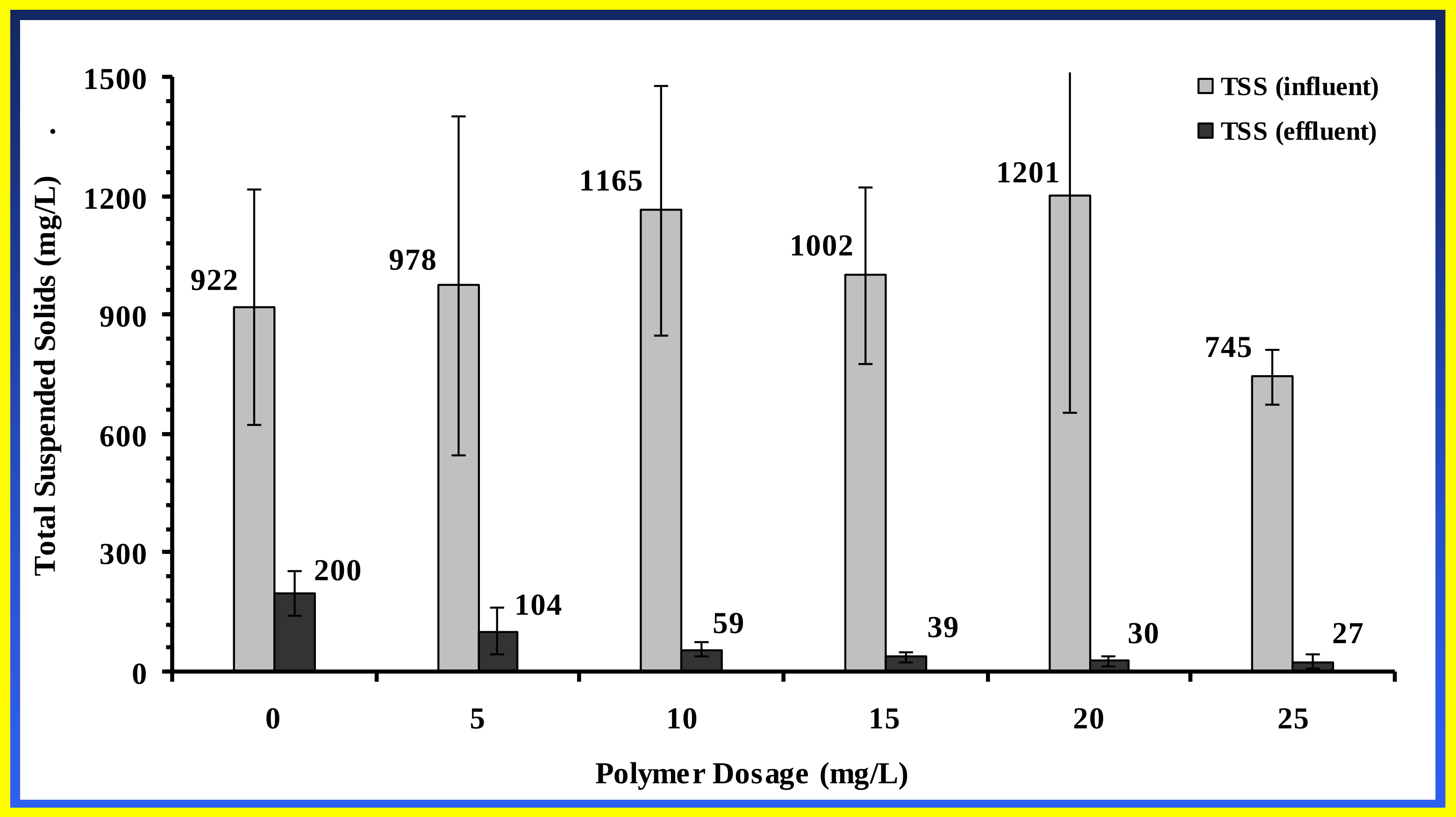
Objectives

- Summary of the current waste treatment systems
- Polymer Selection
- Performance evaluation of Hydrotech Belt filter
    - Alum as Coagulation Aid
    - Polymer as Coagulation Aid
    - Alum and Polymer as Coagulation/Flocculation Aids

Polymer

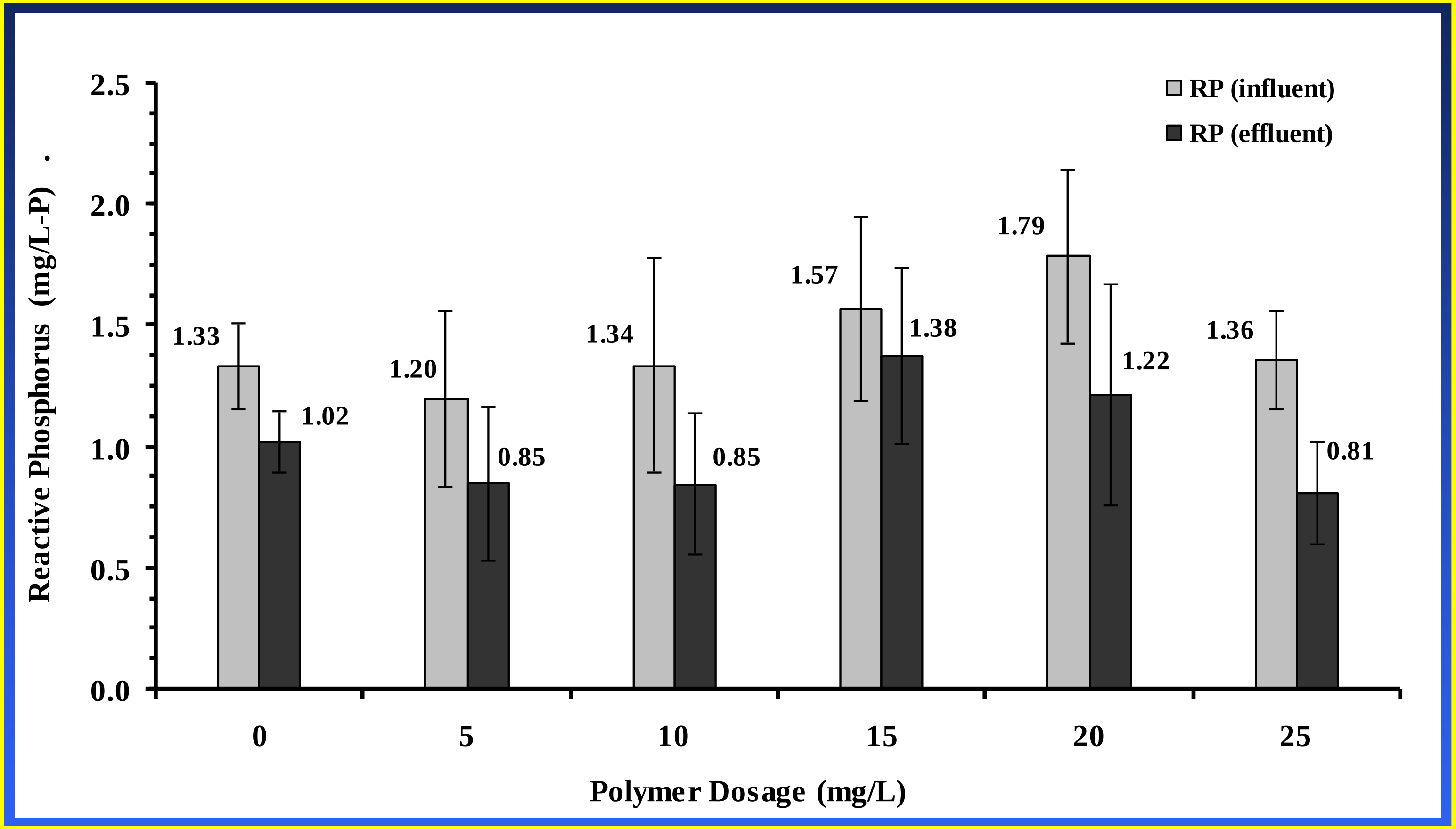
Polymer Dosage		pH	TSS (mg/L) Mean:	TSS StDev:	RP (mg/L-P) Mean:	RP StDev:
0 mg/L (12)	Influent	7.55	922	297	1.33	0.18
	Effluent	7.62	200	55	1.02	0.13
	% Removal		**76.1%**		**23%**	
5 mg/L (8)	Influent	7.52	978	428	1.20	0.36
	Effluent	7.55	104	60	0.85	0.31
	% Removal		**88.6%**		**26%**	
10 mg/L (8)	Influent	7.44	1165	316	1.34	0.44
	Effluent	7.41	59	16	0.85	0.29
	% Removal		**94.7%**		**41%**	
15 mg/L (14)	Influent	7.45	1002	223	1.57	0.38
	Effluent	7.31	39	12	1.38	0.36
	% Removal		**96.0%**		**14%**	
20 mg/L (12)	Influent	7.47	1201	548	1.79	0.36
	Effluent	7.39	30	13	1.22	0.46
	% Removal		**97.3%**		**32%**	
25 mg/L (8)	Influent	7.42	745	69	1.36	0.20
	Effluent	7.31	27	17	0.81	0.21
	% Removal		**96.3%**		**39%**	

Hydrotech Belt Filter



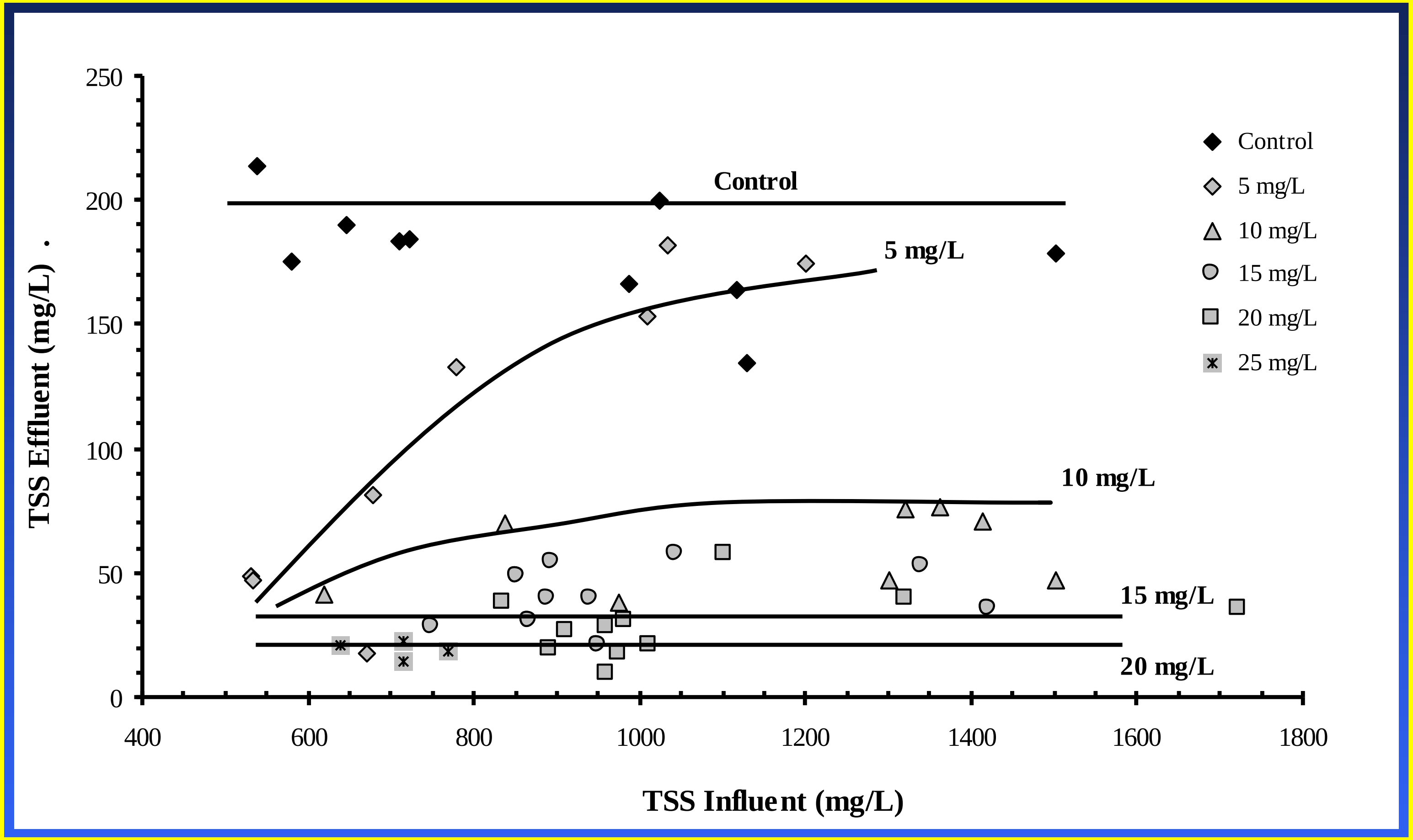
Total suspended solids for the influent from the microscreen backwash sump and effluent from the belt filter as a function of polymer dosage (mg/L).

Hydrotech Belt Filter



Reactive phosphorus for the influent from the microscreen backwash sump and effluent from the belt filter as a function of polymer dosage (mg/L).

Hydrotech Belt Filter



Impact of the influent TSS concentration on the effluent TSS from the belt filter as a function of polymer dosage (mg/L).

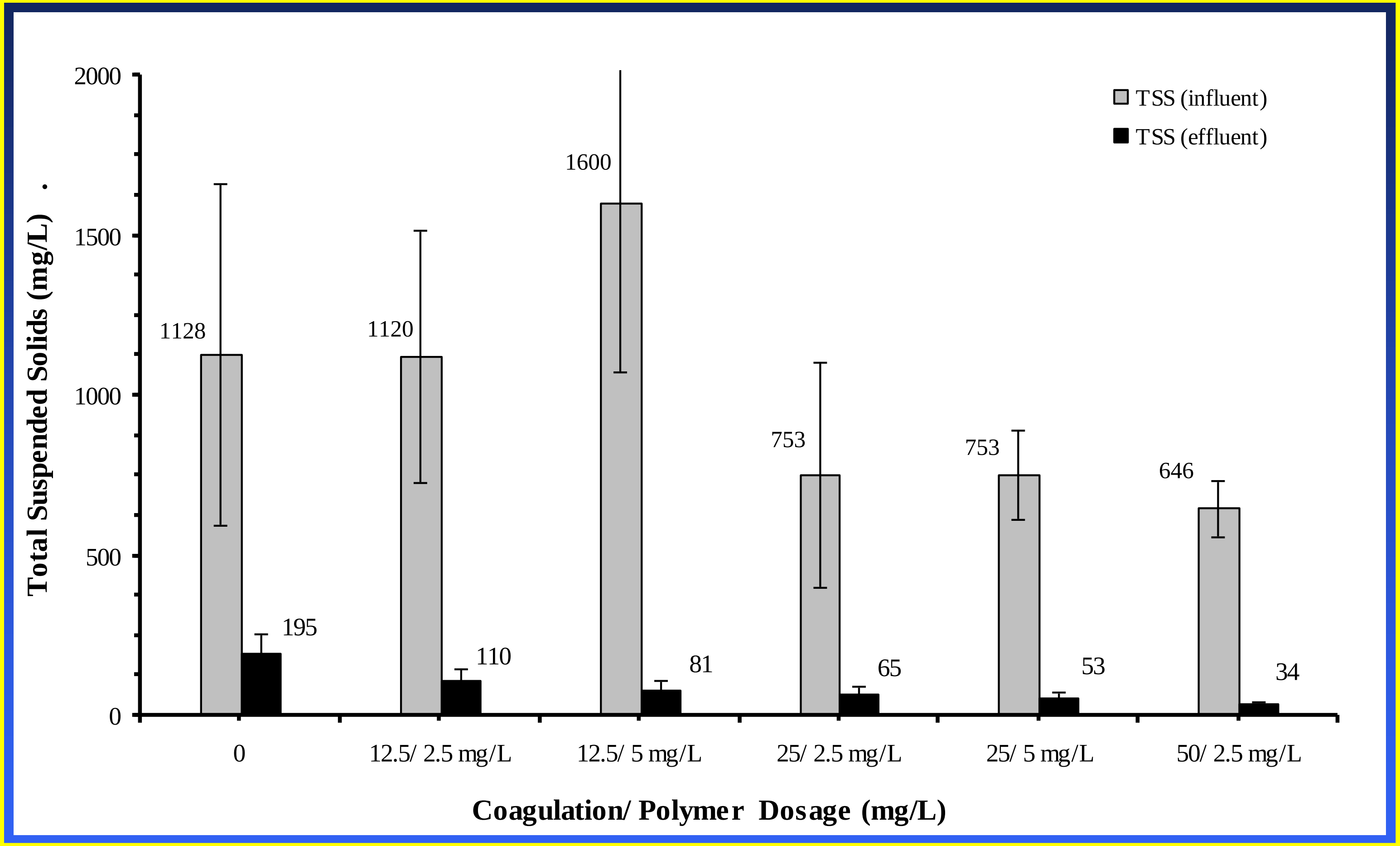
Objectives

- Summary of the current waste treatment systems
- Polymer Selection
- Performance evaluation of Hydrotech Belt filter
  - Alum as Coagulation Aid
  - Polymer as Coagulation Aid
  - Alum and Polymer as Coagulation/Flocculation Aids

Alum/ Polymer

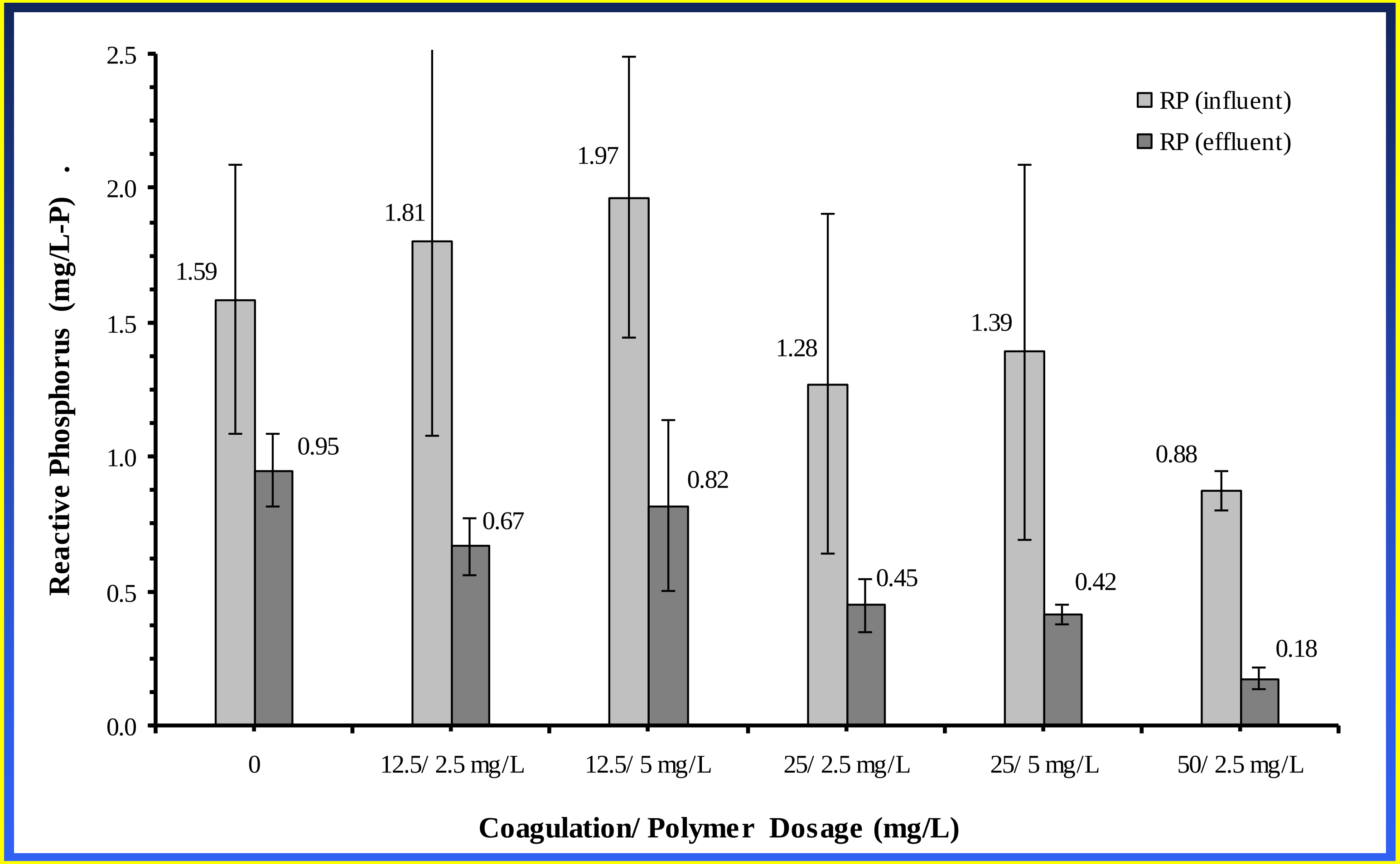
Alum/Polymer Dosage		pH	TSS (mg/L) Mean:	StDev:	RP (mg/L-P) Mean:	StDev:
0 mg/L /	Influent	7.37	1128	534	1.59	0.50
0 mg/L	Effluent	7.39	195	58	0.95	0.14
	% Removal		**81%**		**38%**	
12.5 mg/L /	Influent	7.23	1120	396	1.81	0.73
2.5 mg/L	Effluent	7.26	110	36	0.67	0.11
	% Removal		**90%**		**59%**	
12.5 mg/L /	Influent	7.26	1600	526	1.97	0.52
5 mg/L	Effluent	7.22	81	29	0.82	0.32
	% Removal		**94%**		**55%**	
25 mg/L /	Influent	7.34	753	352	1.28	0.63
2.5 mg/L	Effluent	7.27	65	28	0.45	0.10
	% Removal		**91%**		**57%**	
25 mg/L /	Influent	7.30	753	140	1.39	0.70
5 mg/L	Effluent	7.13	53	20	0.42	0.04
	% Removal		**93%**		**65%**	
50 mg/L /	Influent	7.38	646	87	0.88	0.07
2.5 mg/L	Effluent	7.14	34	11	0.18	0.04
	% Removal		**95%**		**80%**	

Hydrotech Belt Filter



Total suspended solids for the influent from the microscreen backwash sump and effluent from the belt filter as a function of coagulant (alum) and polymer (Hychem CE 1950) dosage (mg/L).

Hydrotech Belt Filter



Reactive phosphorus for the influent from the microscreen backwash sump and effluent from the belt filter as a function of coagulant (alum) and polymer (Hychem CE 1950) dosage (mg/L).

Sludge

- Alum
  - 13.2% ± 1.1
- Polymer
  - 11.6% ± 2.2
- Alum/Polymer
  - 12.6% ± 1.4

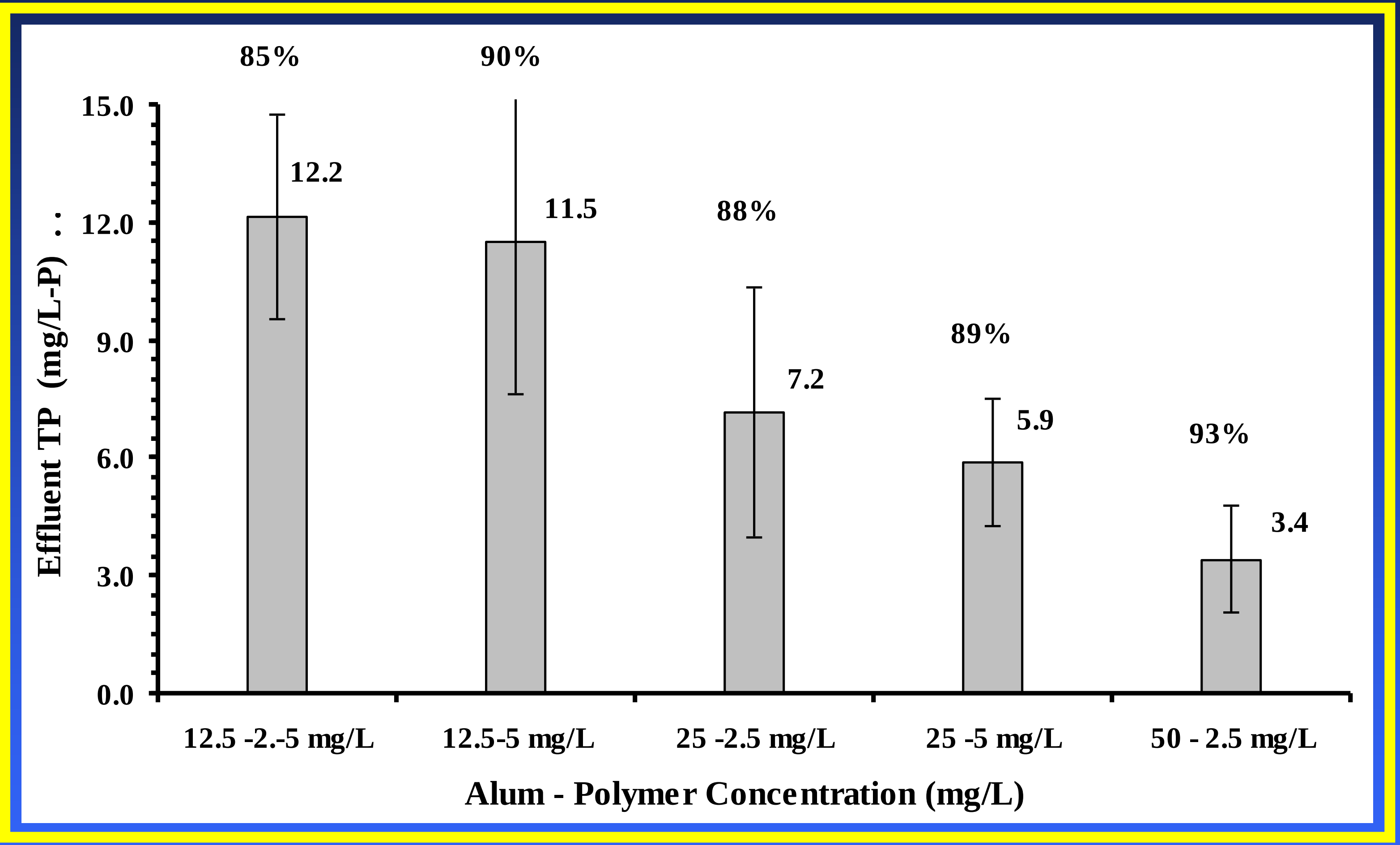
Secondary Objectives

- Other Water Quality Parameters
    - Total Phosphorus
    - Total Nitrogen
    - $cBOD_5$
    - COD

Other Water Quality Parameter

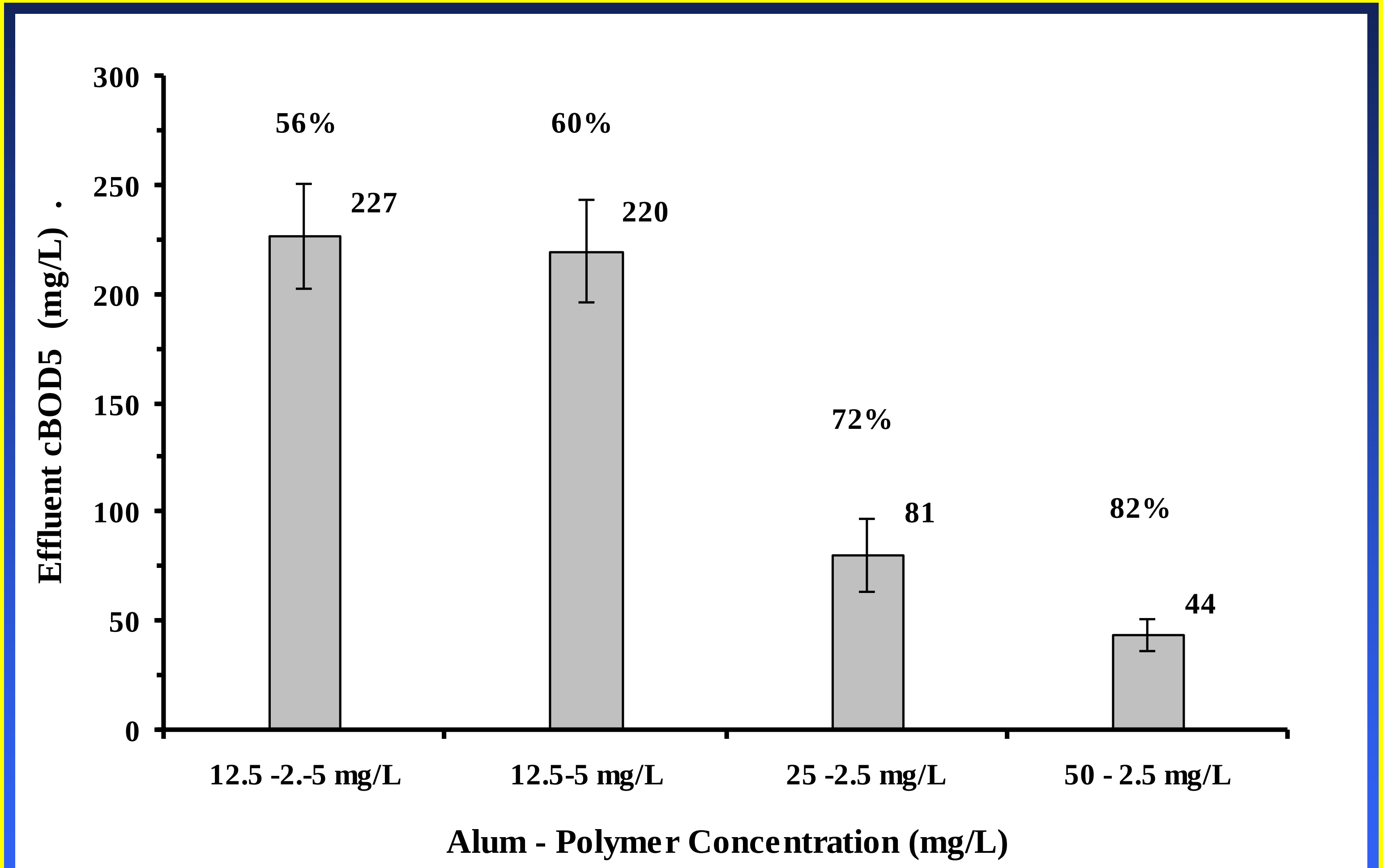
Alum/Polymer Dosage		TP (mg/L-P) Mean:	TP StDev:	TN (mg/L-N) Mean:	TN StDev:	$cBOD_5$ (mg/L) Mean:	$cBOD_5$ StDev:	COD Mean:	COD StDev:
12.5 mg/L / 2.5 mg/L	Influent	95.1	39.9	49.1	20.6	498	89	-----	-----
	Effluent	12.2	2.6	8.5	3.8	227	24	-----	-----
	% Removal	**85%**		**81%**		**56%**			
12.5 mg/L / 5 mg/L	Influent	124	54	95	9.3	549	42	-----	-----
	Effluent	11.5	3.9	16.4	1.7	220	23	----	-----
	% Removal	**90%**		**83%**		**60%**			
25 mg/L / 2.5 mg/L	Influent	705	46.4	36.2	19.8	359	214	758	162
	Effluent	4.7	1.1	4.7	1.1	81	17	112	14
	% Removal	**83%**		**83%**		**72%**		**85%**	
25 mg/L / 5 mg/L	Influent	37	19.8	37	19.8	-----	-----	880	140
	Effluent	7.0	3.0	6.3	2.3	-----	-----	87	22
	% Removal	**88%**		**83%**				**90%**	
50 mg/L / 2.5 mg/L	Influent	50.3	12.4	31.1	6.8	251	50	808	170
	Effluent	3.4	1.4	4.0	1.8	44	8	62	15
	% Removal	**93%**		**87%**		**82%**		**92%**	

Hydrotech Belt Filter



Effluent Total Phosphorus from the belt filter and percent removal for the microscreen backwash wastewater as a function of coagulant (alum) and polymer (Hychem CE 1950) dosage.

Hydrotech Belt Filter



Effluent $cBOD_5$ from the belt filter and percent removal for the microscreen backwash sump wastewater as a function of coagulant (alum) and polymer (Hychem CE 1950) dosage (mg/L).

Economics

Polymer	Cost of Polymers	Cost per kg	Cost per metric tonne of feed
LT 7991	$247.50 / 450lb drum	$1.21	$7.26
LT 7992	$148.50 / 450 lb drum	$0.73	$4.38
LT 7995	$252.00/ 450 lb drum	$1.23	$7.38
CE 854	$418.50/ 450 lb drum	$2.05	$13.08
CE 1950	$418.50/ 450 lb drum	$2.05	$13.08

Hydrotech Belt Filter

Unexpected Difficulties

Polymer induced foam at high dosage

Conclusions

- Alum: 96% of RP, 0.07 mg/L-P
- Polymer: 96% of TSS, 30 mg/L
- Alum/Polymers: 95% of TSS and 80% of RP
- Sludge: 13% solids

- TP 93%,
- TN 87%,
- BOD_5 82%,
- COD 92%

Future Research

- Continued evaluation of other potential coagulant aids, such as Acid Mine Drainage Sludge
- Evaluation of other polymer
- Increase belt porosity to improve Hydraulic Loading Rate
- Additional performance evaluation of belt filter systems in terms of several operating parameters, including flow rates and belt speed.

Acknowledgements

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Questions ?