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

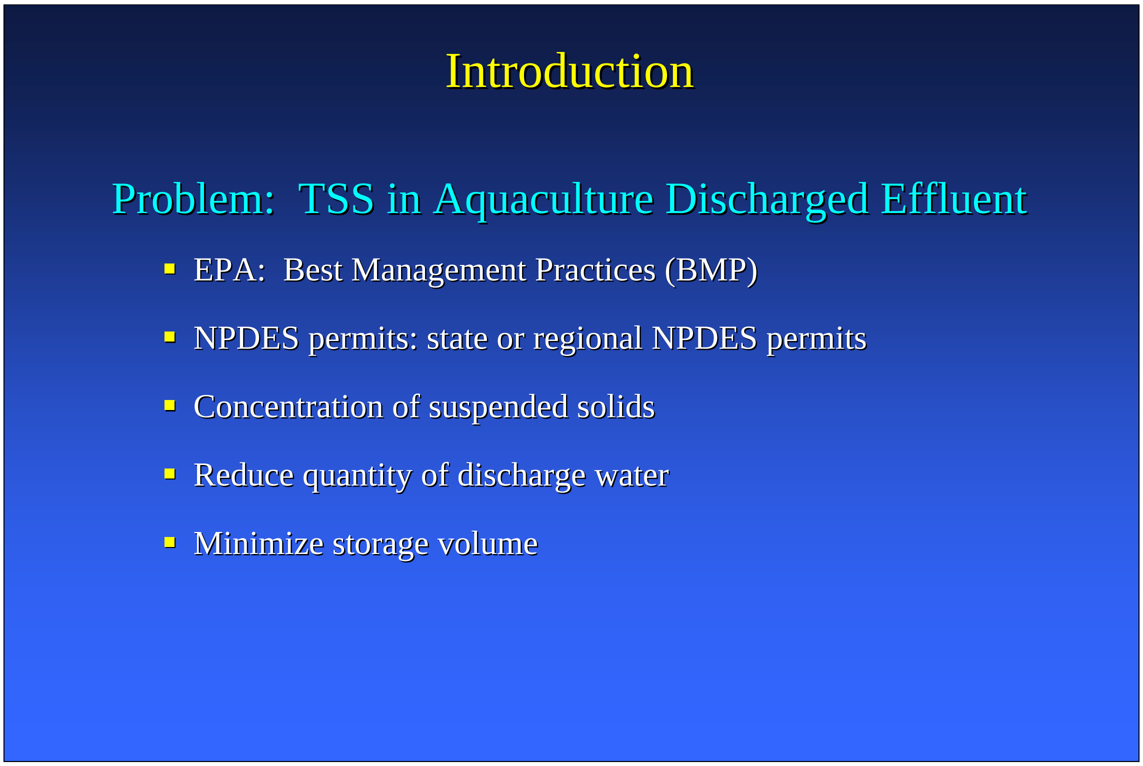
James M. Ebeling, Ph.D.
Research Engineer
Aquaculture Systems Technology

Carla F. Welsh
Research Associate
The Conservation Fund
Freshwater Institute

Kata L. Rishel
Research Assistant
The Conservation Fund
Freshwater Institute

The Hydrotech® Belt Filter is designed to thicken sludge from the backwash water of a microscreen filter, when used in conjunction with a coagulation / flocculation and polymer mixing system. By eliminating settling tanks or ponds, leaching of nutrients (phosphorus, nitrogen) is minimized and the dewatered sludge is in a form for easy transport and disposal. Typically, sludge from the drum filter used to treat the discharge of a partial reuse system at the Conservation Funds Freshwater Institute has a dry matter content of 0.06 – 0.14% (600 – 1400 mg/L). After passing through the Hydrotech Belt Filter, tests show the dry matter content increased to approximately 15%.

Testing of the Hydrotech coagulation/flocculation system was completed using the backwash effluent from a partial reuse and intensive recirculating aquaculture systems at the Conservation Funds Freshwater Institute. Alum was used as the coagulant aid because of its availability in dry form for easy storage and mixing. Alum used alone as a coagulant aid was not as efficient in removing solids (83%) as was expected based on standard jar tests, but was very efficient in sequestering reactive phosphorus (96%), with effluent concentrations less than 0.07 mg/L-P at 100 mg/L alum. Several different polymers were evaluated using the standard Jar Test to determine optimum dosing and mixing requirements. Polymers used alone and at relatively low dosages (15 mg/L) were very efficient in removing suspended solids, with a removal rate averaging 96% and an effluent TSS concentration of less than 30 mg/L. At the optimum dosage of alum and polymer, the Hydrotech Belt Filter System increased the dry matter content of the sludge to approximately 13% solids, and reduced both the suspended solids and soluble phosphorus concentration of the effluent by 95% and 80% respectively. In addition, significant reductions in total phosphorus, total nitrogen, cBOD5, and COD were seen. The combination of coagulation/flocculation aids and the Hydrotech Beltfilter show excellent potential



As environmental regulations become more stringent, environmentally sound waste management and disposal are becoming increasingly more important in all aquaculture operations. One of the primary water quality parameters of concern is the suspended solids concentration in the discharged effluent.

As environmental regulations become more stringent, environmentally sound waste management and disposal are increasingly more important in all aquaculture operations. Two of the primary concerns are the suspended solids and phosphorus in the discharged effluent. For example, EPA initially considered the establishment of numerical limitations for only one single pollutant – total suspended solids (TSS). For recirculation systems, the proposed TSS limitations would have applied to solids polishing or secondary solids removal technology. The new rules and regulations from EPA (August 23, 2004) require only qualitative TSS limits, in the form of solids control Best Management Practices (BMP), allowing individual regional and site specific conditions to be addressed by existing state or regional programs through NPDES permits. In recirculation systems, microscreen filters are commonly used to remove the suspended solids from the process water, because they require minimal labor and floor space and can treat large flow rates of water with little head loss. In addition, microscreen filters generate a separate solids waste stream that can be further concentrated to reduce the quantity and improve the quality of discharge water and minimize storage volume required during over wintering for land disposal or other final disposal options.

In addition to suspended solids, phosphorus is one of the most scrutinized nutrients discharged by aquaculture systems, due to its potential for eutrophication of receiving waters. While some progress has been made in reducing the phosphorus content of feeds, few attempts have been made to reduce the phosphorus levels in

Hydrotech Belt Filter (Water Management Technologies)

Belt Filter System, Hydrotech Model HBF537-1H

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

Inclined belt filters are one of the newest technologies to manage aquaculture effluent waste stream, and they have been specifically designed to thicken sludge from the backwash water of a microscreen filter. Testing of the Belt Filter System, Hydrotech Model HBF537-1H, from Waste Management Technologies, Inc., Baton Rouge, LA, USA coagulation/flocculation system was conducted using the backwash effluent from several aquaculture production systems at the Conservation Funds Freshwater Institute in Shepherdstown, WV. Alum was used as the primary coagulation aid because it is readily availability in dry form and its ease of storage and mixing. A commercially available polymer was used as the flocculation aid. The coagulation/flocculation system was plumbed in to treat the waste discharge stream of a microscreen filter used as final treatment of discharge water from several large-scale recirculating aquaculture production systems growing arctic char and trout. The objectives of this research were to evaluate the effectiveness of the Belt Filter System for treating a recirculating system's microscreen backwash effluent and to determine the optimal dosage of alum and polymer used separately or in combination for the removal of suspended solids and phosphorus.

Objectives

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

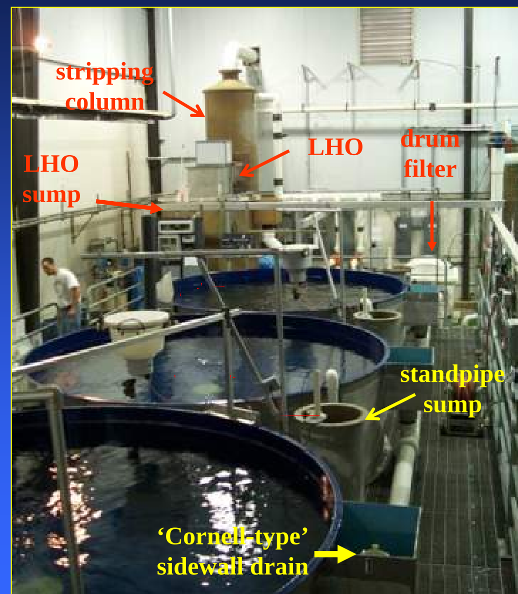
Over the past several years, The Conservation Funds Freshwater Institute has researched and demonstrated several technologies and strategies to manage and reduce the wastes generated during aquaculture production, including improved feed and feeding strategies (Tsukuda et al., 2000), technologies to minimize water use and concentrate waste streams (Timmons and Summerfelt, 1997; Summerfelt et al., 2000) and overall waste management and treatment reviews (Summerfelt, 1998; Summerfelt, et al., 1999; Ebeling & Summerfelt, 2002). Using standard laboratory jar tests, the application of several coagulation aids (alum and ferric chloride) for treating the supernatant from settling cones was investigated by Ebeling et al. (2003) and for backwash water from microscreen filters, Ebeling et al, (2004). In addition, a screening and evaluation of several commercially available polymers was conducted using laboratory jar tests to determine their effectiveness as coagulation/flocculation aids for aquaculture effluents, Ebeling et al. (2005). Finally, a series of laboratory jar tests were conducted to evaluate the effectiveness of using a combination of alum and a polymer, Rishel and Ebeling (2005).

The waste stream for treatment was taken directly from the holding tanks receiving the backwash water from several rotating microscreen filters used for suspended solids removal in two commercial size recirculating production systems growing arctic charr and trout. The first of these is a pilot-scale partial-reuse system consisting of three 3.66 m x 1.1 m deep circular 'Cornell-type' dual-drain culture tanks with a maximum feed loading rate of 45-50 kg of feed per day (Summerfelt et al., 2004a). The second system is a fully-recirculating system consisting of a 150 m^3 circular production tank with a maximum daily feed rate of 200 kg of feed per day (Summerfelt et al, 2004b). Because of the excess alkalinity of the spring water at this location, no alkalinity additions were required in conjunction with alum treatment.

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

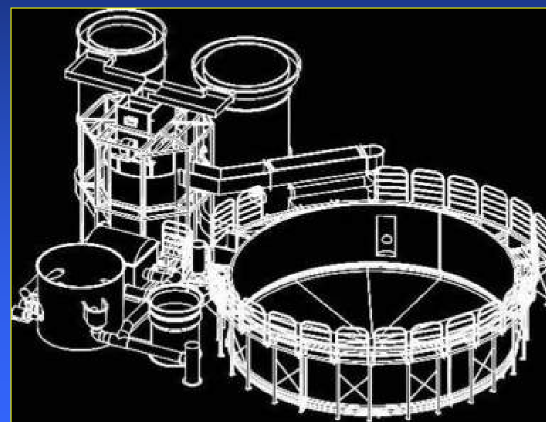


The Freshwater Institute's pilot-scale partial-reuse system ,above, consists of three 3.66 m by 1 m deep circular Cornell-type' dual-drain culture tanks (Summerfelt, et.al., 2000). The Cornell-type' dual-drain tank provides for efficient and effective solids removal by concentrating and flushing the suspended solids through the tank's bottom-center drain. In a recent study, the total suspended solids concentrated discharge through the three culture tanks' bottom-center drains average 26.2 ± 2.1 mg/L, compared to 2.5 ± 0.2 mg/L through the elevated side-wall drain (Summerfelt, et al., 2000). In the current system, approximately 5 - 20% of the flow is discharged through a bottom-center drain and the remaining flow exists through an elevated side-wall drain located at the water surface. The flow from the bottom-center drain is continuously discharged directly to the treatment system located in the greenhouse. The remaining discharge, 80-95% of the recirculating flow, is collected and filtered through a rotating drum filter (Model RFM 3236, PRA Manufacturing, Ltd., Nanaimo, British Columbia, Canada) equipped with 90 µm mesh screens, before it enters a pump sump. The water is then pumped by several 1.2 kW centrifugal pumps through a packed aeration column for aeration and carbon dioxide stripping. The water exits the aeration column and flows through a low head oxygenator (Model MS-LHO-400 gpm, aluminum construction, PRA Manufacturing Ltd., Nanaimo, British Columbia, Canada) installed within a cone-bottom sump. The water then flows by gravity back to the three production tanks and is discharge at multiple sidewall ports to provide for water circulation. The systems water's pH is controlled by adjusting the amount of carbon dioxide stripped in the aeration column by turning a forced air fan "on and off". The fan is controlled by a pH controller (GLI International, Milwaukee, Wisconsin). Monitoring systems track the dissolved oxygen, pH, temperature, make-up water, and total flow rates through the system. In addition, supplemental or emergency oxygen is available by in-tank oxygen diffusers, controlled both manually and by the dissolved oxygen monitoring system. Currently the system is operating at a total flow rate of from 1200 to 1900 lpm (300-475 gpm), with a bottom-center discharge rate of 170 to 220 lpm (45-60 gpm), and a

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.)

The Freshwater Institutes Recirculating Growout System is constructed around a 150 m^3 production tank, 9 m in diameter and 2.5 m deep circular ‘Cornell-type’ dual-drain culture tanks, currently growing artic charr and rainbow trout. As with the partial-reuse system, the ‘Cornell-type’ dual-drain tank provides for efficient and effective solids removal by concentrating and flushing the suspended solids through the tank’s bottom-center drain. Under the current operating parameters, approximately 3-7% of the flow is discharged through the tank’s bottom-center drain and the remaining 93-97% of the flow through an elevated side-wall discharge. The total flowrate is 4,750 L/min or a Hydraulic Retention Time (HRT) in the production tank of 31.5 minutes. The solids laden flow from the bottom-center drain is discharged into a swirl separator and then combined with the side-wall stream and filtered through a rotating drum filter (Model RFM 4848, PRA Manufacturing, Ltd., Nanaimo, British Columbia, Canada) equipped with 60 µm mesh screens, before it enters a pump sump. The discharge from the swirl separator flows is combined with the overflow from the sump and flows to the greenhouse sump. Three 3.75 kW pumps (one dedicated backup) provide a flow rate of approximately 4,750 Lpm to a fluidized sand filter, (Cyclo BiofilterTM), 2.7 m in diameter and 6.1 m tall. The static sand capacity is approximately 8.5 m^3 or a depth of 1.5 m. The Cyclo BiofilterTM had a design TAN assimilation capacity of 200 kg of feed/day or 0.7 kg TAN/m^3/day. After leaving the biofilter, the water flows through a stripping column to remove excess CO2 and into a Low Head Oxygenator (LHO), which increases the water DO concentration to approximately 14 mg/L. The LHO can be used either for oxygen supplementation or ozone can be added for disinfection purposes. Finally an inline Horizontal channel UV filter is used to reduce the heterotrophic plat count and in addition, destroys any residual dissolved ozone. The system is currently stocked with Artic char at close 100 kg/m^3 or a biomass of 13,500 kg. Approximately, 100 kg of feed is currently fed per day.

Current Aquaculture Waste Management

Polishing Microscreen Filter
Model RFM 4848, Manufacturing, Ltd.

Backwash Water Sump

Microscreen filters for filtration have become very popular for suspended solids removal, because they require minimal labor and floor space and can treat large flow rates of water with very little head loss. Screen filters remove solids by virtue of physical restrictions (or straining) on a media when the mesh size of the screen is smaller than the particles in the wastewater. Microscreen filters, though, generate a separate solids waste stream that must be further processed before final discharge. The backwash flow will vary in volume and solids content will vary based on several factors. These are the screen opening size, type of backwash control employed, frequency of backwash, and influent TSS load on the filter. Backwash flow is generally expressed as a percentage of the flow the filter treats, with reported backwash flows ranging from 0.2 to 1.5% of the treated flow. At Freshwater Institute, each of the three microscreen filter's backwash discharge is directed to a pump sump, whose size depends on the source stream. The largest of these is for the recirculating growout system and consists of a 1500 gal concrete septic tank located just outside of the wetlab building. The other two filters use smaller 1000 L polyethylene tanks. In each of these tanks, a submersible pump and a float switch that pumps down the tanks when they reach a preset level. Each pump is connected to a separate line to three settling cones located in a greenhouse.

Current Aquaculture Waste Management

The Freshwater Institute has successfully applied the concept of settling basins to concentrating the backwash coming off of the drum filters. Three off-line settling cones or thickening tanks are used to capture and store solids from the intermittent backwash of three drum filters. The solids-laden backwash flow is introduced intermittently into the top and center of each tank. At the top of each tank, the flow is introduced within a cylinder with an open bottom that is centered within the tank. The cylinder improves the hydraulics of the tank's radial flow by directing the water to first flow down (underneath the cylinder and towards the cone of the tank) and then up as it travels radially towards the effluent collection launder about the top circumference of the tank. These thickening tanks have performed well, capturing 97% of the solids discharged from the microscreen filter backwash flows. In addition, the three settling cones are plumb such that the three waste streams can be directed to a single cone or multiple cones.

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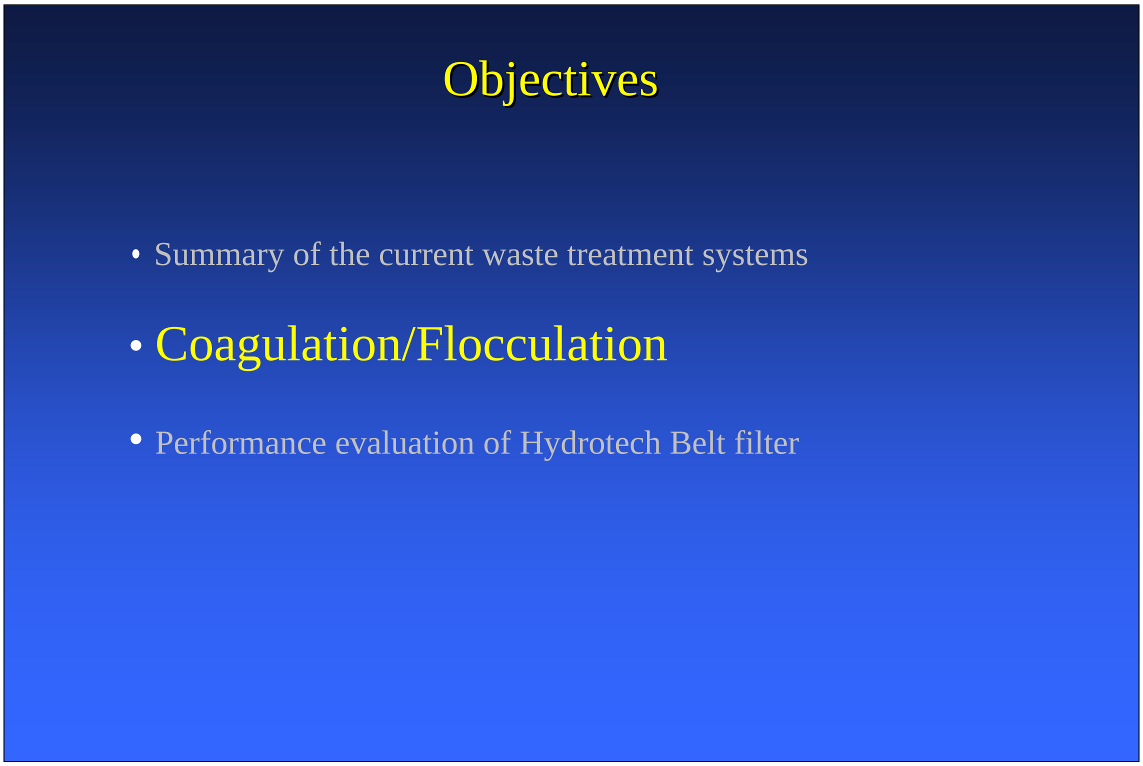
After sufficient wastes have collected in the settling cones, they are individually pump out with a standard farm “honey wagon”. i.e. a vacuum pump systems. The solids are then distributed either on pasture land used for hay production or on windrows of mulch for composting. The treated waste stream discharges into a aerobic settling pond, which removes some of the remaining BOD and some phosphorus.

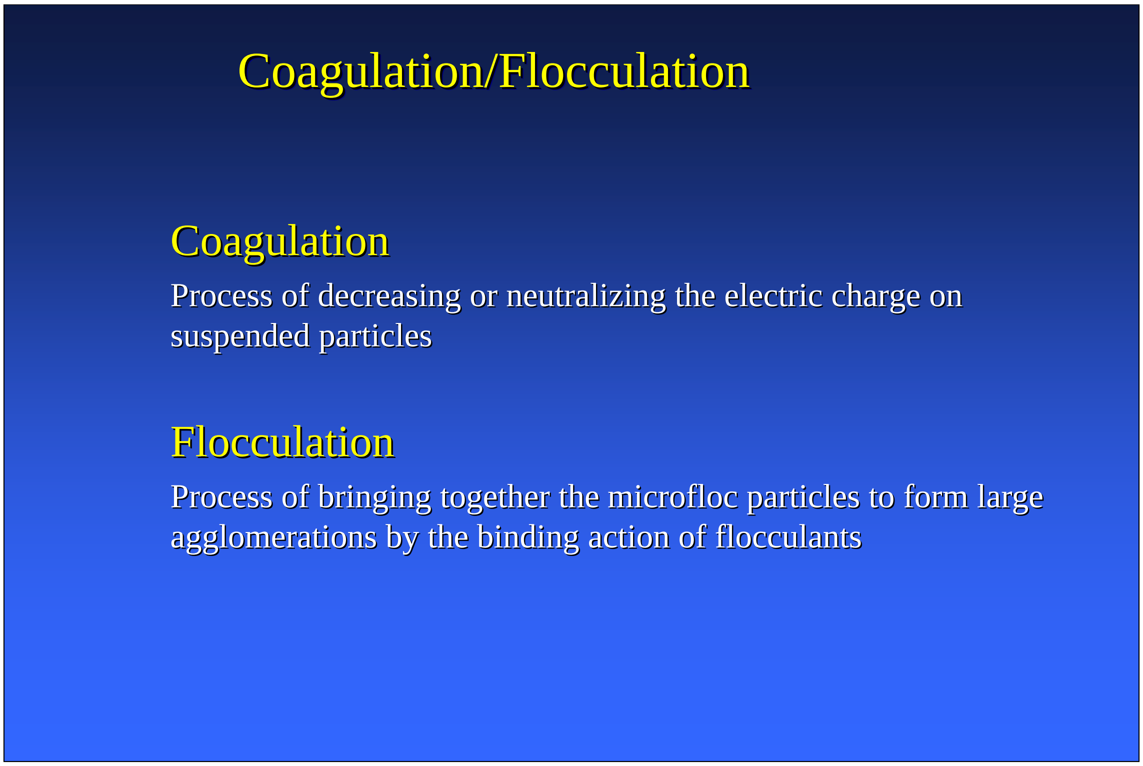
Waste Management – Discharge Parameters

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

Water quality characteristics of the microscreen backwash effluent are summarized in the above table. Because of the excess alkalinity of the water at this location i.e. approximately 260 mg/L as $CaCO_3$, no alkalinity additions were required in conjunction with alum and ferric chloride treatments.



One of the most commonly used methods for the removal of suspended solids in drinking water is the addition of coagulant and flocculation aids, such as alum and long chain polymers (AWWA, 1997).



Coagulation is the process of decreasing or neutralizing the electric charge on suspended particles or zeta potential. Like electric charges on small particles in water cause them to naturally repel each other and hold the small, colloidal particles apart, keeping them in suspension. The coagulation/flocculation process neutralizes or reduces the negative charge on these particles, which then allows the van der Waals force of attraction to encourage initial aggregation of colloidal and fine suspended materials to form microfloc. Flocculation is the process of bringing together the microfloc particles to form large agglomerations by physically mixing or through the binding action of flocculants, such as long chain polymers.

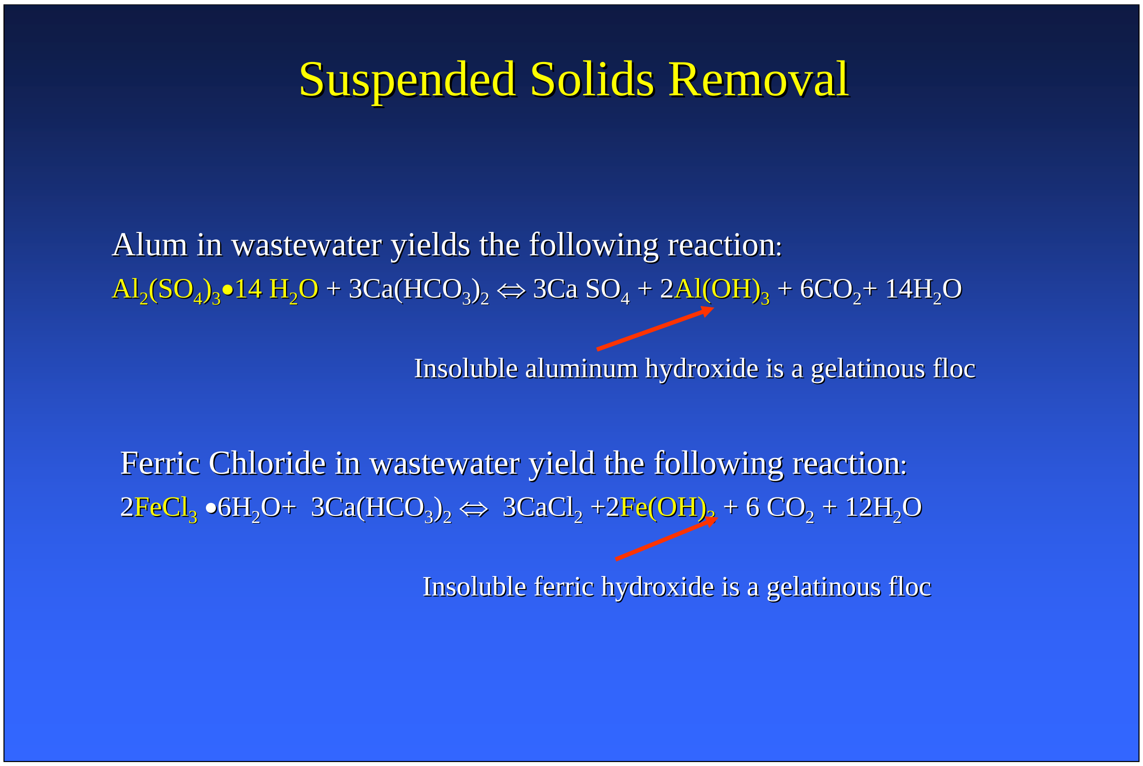
A classical coagulation/flocculation unit process (Metcalf and Eddy 1991) consists of three separate steps:

Rapid or Flash Mixing: the suitable chemicals (coagulants/ flocculants and if required pH adjusters) are added to the wastewater stream, which is stirred and intensively mixed at high speed.

Slow Mixing (coagulation and flocculation): the wastewater is only moderately stirred in order to form large flocs, which are easily settled out.

Sedimentation: the floc formed during flocculation is allowed to settle out and is separated from the effluent stream.

Numerous substances have been used as coagulant and flocculation aids, including alum [$Al_2(SO_4)_3 \cdot 18H_2O$], ferric chloride [$FeCl_3 \cdot 6H_2O$], ferric sulfate [$Fe_2(SO_4)_3$], ferrous sulfate [$FeSO_4 \cdot 7H_2O$] and lime [$Ca(OH)_2$] (Metcalf and Eddy 1991).



Aluminum sulfate (alum) is the most commonly used coagulant and is easy to handle and apply and produces less sludge than lime. Its primary disadvantage is that it is most effective over a limited pH range of 6.5 to 7.5. Ferric chloride is also a commonly used coagulant and is effective over a wider pH range of 4 to 11. The ferric hydroxide floc is also heavier than the alum floc, improving its settling characteristics, and reducing the size of the clarifier. Neither ferric sulfate nor ferrous sulfate is commonly used today, but ferric sulfate is slowly replacing ferric chloride because it is easier to store and handle. Lime is commonly used and is effective, but is quite pH dependent and produces a large quantity of sludge requiring disposal.

When alum is added to a wastewater, the following reaction takes place:

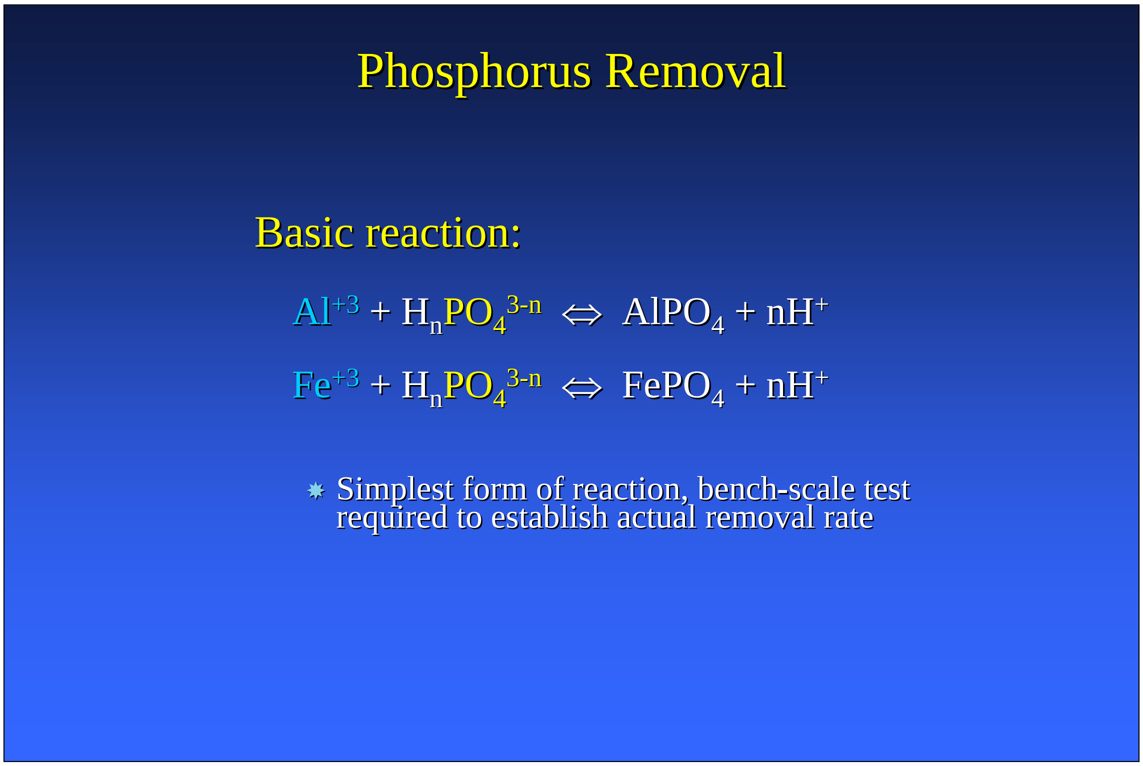
$$Al_2(SO_4)_3 \cdot 18\ H_2O + 3\ Ca(HCO_3)2 \Leftrightarrow 3\ CaSO_4 + 2\ Al(OH)_3 + 6\ CO_2 + 18\ H_2O \qquad (1)$$

The insoluble aluminum hydroxide, $Al(OH)_3$, is a gelatinous floc that settles slowly through the wastewater, sweeping out the suspended material. Alkalinity is required for the reaction and if not available, must be added at the rate of 0.45 mg/L as $CaCO_3$ for every 1 mg/L alum.

Similarly, for ferric chloride:

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

The insoluble ferric hydroxide, $Fe(OH)_3$, is also a gelatinous floc that settles through the wastewater, sweeping out the suspended material. Alkalinity is required for the reaction and if not available, must be added at the rate of 0.55 mg/L $CaCO_3$ for every 1 mg/L ferric chloride.



In addition, both aluminum and iron salts can also be used for the chemical precipitation of phosphorus. The basic reactions involved are:

$$Al^+_3 + PO4^-_3 \Leftrightarrow AlPO_4 \qquad (3)$$

$$Fe^+_3 + PO4^-_3 \Leftrightarrow FePO_4 \qquad (4)$$

The above equations are the simplest forms of the reaction (Metcalf and Eddy 1991, Lee and Lin 2000). Due to the many other competing reactions, the effects of alkalinity, pH, trace elements, and other compounds in the wastewater, the actual chemical dosage required to remove a given quantity of phosphorus is usually established on the basis of bench-scale test or sometimes pilot-scale tests.

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

Recently, the use of high molecular weight long-chain polymers has been used as replacement to alum and ferric chloride for flocculation of suspended solids.

Advantages of the polymers are:

- lower dosages requirements,
- reduced sludge production,
- easier storage and mixing,
- both the molecular weight and charge densities can be optimized creating “designer” flocculant 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

Polymers or polyelectrolytes consist of simple monomers that are polymerized into high-molecular-weight substances (Metcalf and Eddy, 1991) with molecular weights varying from 104 to 106 Daltons. Polymers can vary in molecular weight, structure (linear versus branched), amount of charge, charge type and composition. The intensity of the charge depends upon the degree of ionization of the functional groups, the degree of copolymerization and/or the amount of substituted groups in the polymer structure (Wakeman and Tarleton, 1999). With respect to charge, organic polymers can be cationic (positively charged), anionic (negatively charged) or nonionic (no charge). Polymers in solution generally exhibit low diffusion rates and raised viscosities, thus it is necessary to mechanically disperse the polymer into the water. This is accomplished with short, vigorous mixing (velocity gradients,G values of 1500 sec-1, although smaller values have been reported in the literature, 300 to 600 sec-1) to maximize dispersion, but not so vigorous as to degrade the polymer or the flocs as they form (Wakeman and Tarleton, 1999).

The effectiveness of high molecular weight long-chain polymer treatment of aquaculture wastewater depends on the efficiency of each stage of the process: coagulation, flocculation, and solids separation. In turn, the process efficiency can depend on:

•polymer concentration,

•polymer charge (anionic, cationic, and nonionic),

•polymer molecular weight and charge density,

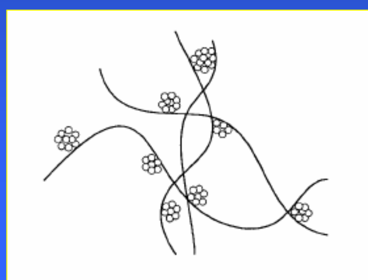
•raw wastewater characteristics (particle size, concentration, temperature, hardness, pH),

•physical parameters of the process (dosage, mixing energy,

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



Polyelectrolytes act in two distinct ways: charge neutralization and bridging between particles. Because wastewater particles are normally charged negatively, low molecular weight cationic polyelectrolytes can act as a coagulant that neutralizes or reduces the negative charge on the particles, similar to the effect of alum or ferric chloride. This has the effect of drastically reducing the repulsive force between colloidal particles, which allows the van der Waals force of attraction to encourage initial aggregation of colloidal and fine suspended materials to form microfloc. The coagulated particles are extremely dense, tend to pack closely, and settle rapidly. If too much polymer is used, however, a charge reversal can occur and the particles will again become dispersed, but with a positive charge rather than negatively charged.

Higher molecular weight polymers are generally used to promote bridging flocculation. The long chain polymers attach at a relatively few sites on the particles, leaving long loops and tails which stretch out into the surrounding water. In order for the bridging flocculants to work, the distance between the particles must be small enough for the loops and tails to connect two particles. The polymer molecule thus attaches itself to another particle forming a bridge. Flocculation is usually more effective the higher the molecular weight of the polymer. If too much polymer is used however, the entire particle surface can become coated with polymer, such that no sites are available to "bridge" with other particles, the 'hair-ball effect'. In general, high molecular weight polymers produce relatively large, loosely packed flocs, and more fragile flocs (Wakeman and Tarleton, 1999).

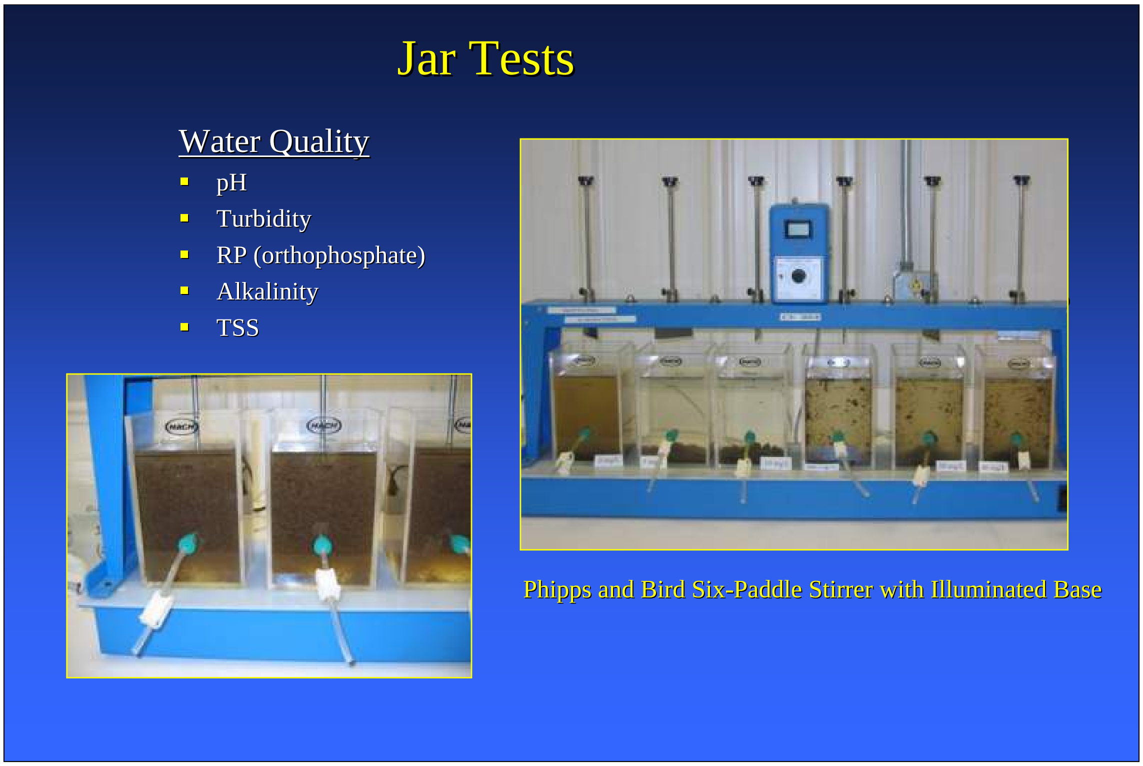
Polymer Evaluation

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

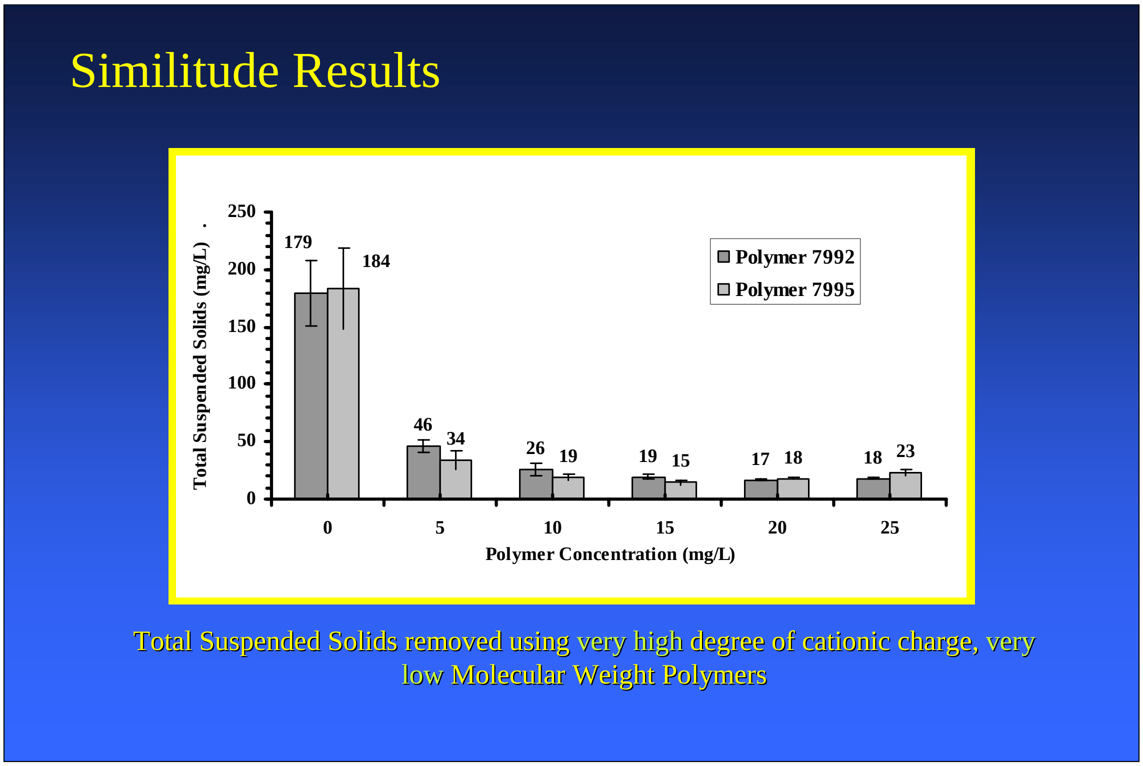
Because the chemistry of wastewater has a significant effect on the performance of a polymer, as well as alum, the selection of a type of polymer and dosage generally requires testing with the targeted waste stream and the final selection is often more of an "art" than a science. Hundreds of polymers are available from numerous manufactures with a wide variety of physical and chemical properties. And, although the manufactures can often help in a general way, the end user must often determine from all the various product lines which is best for their particular application and waste stream.

Since coagulant/flocculant interactions are very complex, laboratory studies, i.e. jar tests, are used to determine the optimal dosage, duration, and intensity of mixing and flocculation. The coagulation-flocculation process consists of three distinct steps. First, the coagulant is added to the effluent water and a rapid and moderately intensity mixing is initiated. The objective is to obtain complete mixing of the coagulant with the wastewater to maximize the effectiveness of destabilization of colloidal particles and initiate coagulation. Second, the polymer is added and intensive mixing is used to completely disperse the polymer through out the effluent water. Third, the suspension is slowly stirred to increase contact between coagulating particles and to facilitate the development of large flocs via the polymer. Again, the flocculation duration and intensity are critical parameters. As for example too high intensity can break up the aggregate floc.



A standard jar test apparatus, the Phipps & Bird Six-Paddle Stirrer with Illuminated Base was employed for the initial screening tests, with six 2-liter square B-Ker2 Plexiglas jars. The jars are provided with a sampling port, 10 cm below the water line, which allows for repetitive sampling with minimal impact on the test. The six flat paddles are all driven by a single variable speed motor from 0 to 300 rpm. An illuminated base helps observation of the floc formation and settling characteristics. For additional information on the jar test procedure, see Ebeling et al., (2004), Ebeling et al., (2005), Rishel and Ebeling, (2005). For all of the jar tests, pH, turbidity, and Soluble Reactive Phosphorus (SRP, orthophosphate) were measured. For the purpose of comparing the effect of various operating parameters such as mixing and flocculation speed, turbidity was used as an indicator of suspended solids and orthophosphate for phosphorus content.

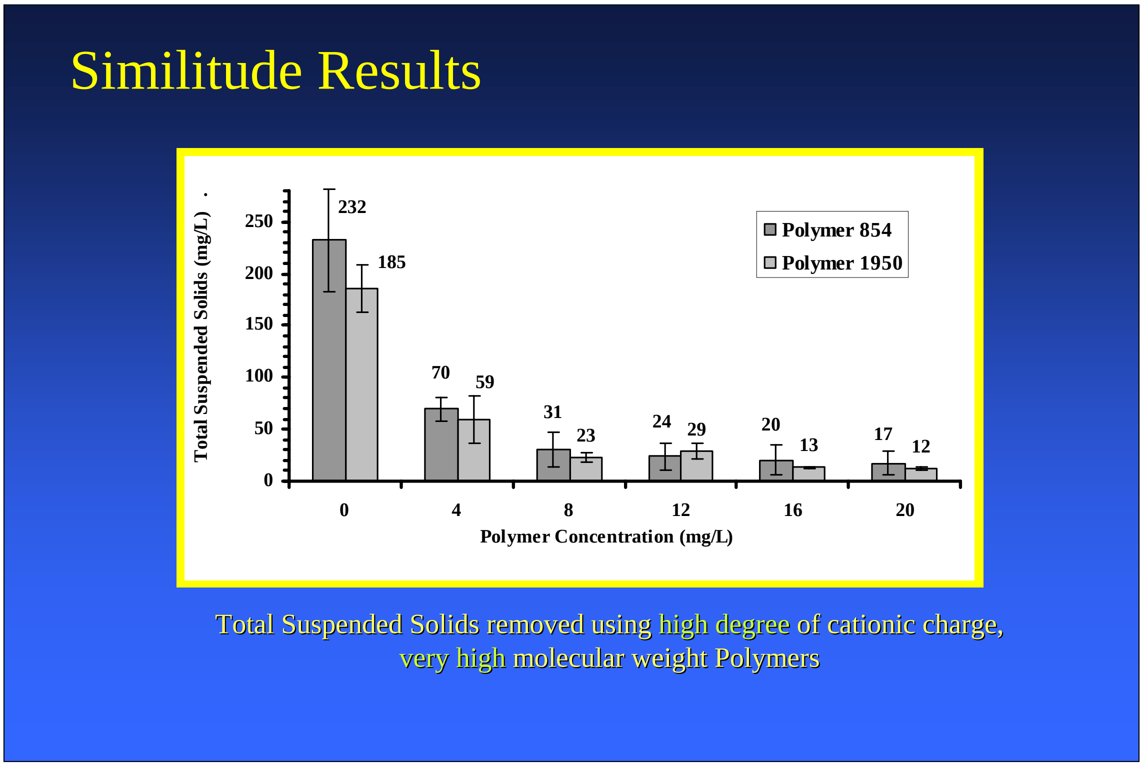
A series of jar tests were carried out with alum to determine the dosages and conditions (mixing and flocculation stirring speeds, durations, and settling times) required to achieve optimum waste capture (ASTM, 1995; Ebeling et al., 2004). Optimum suspended solids removal was achieved with a 60 mg/L dosage of alum, reducing TSS from an initial influent value of approximately 320 mg/L to an effluent of approximately 10 mg/L. In addition at a dosage of 60 mg/L, the reactive phosphorus removal efficiency for alum was greater than 90%. Flocculation and mixing speed and duration played only a minor role in the removal efficiencies for both orthophosphates and suspended solids. Both coagulation-flocculation aids also exhibited excellent settling characteristics, with the majority of the floc quickly settling out in the first five minutes.



In addition, a series of jar tests were conducted to screen a wide range of commercially available polymers and evaluate the performance of a small subset which showed potential for use with aquaculture microscreen backwash effluent (Ebeling et al., 2005). Although a wide range of types of polymers were used, the results show excellent removal efficiencies for all of them with suspended solids removal close to 99% and a final TSS values ranging from as low as 10 to 17 mg/L. Although polymers are not intended to be used for phosphorus removal, reactive phosphorus was reduced by 92 to 95% by removing most of the TSS in the wastewater.

Finally, a series of Jar Tests using both alum and a polymer were conducted to determine the dosages required to achieve optimum removal for both suspended solids and reactive phosphorus (Rishel and Ebeling, 2005). With several different alum/polymer combinations, i.e. 50 mg/L alum and 5 mg/L cationic polyacrylamide polymer, percent removal rates were as high as 99% for suspended solids, reactive phosphorus, and total phosphorus. With final concentrations of suspended solids less than 10 mg/L, reactive phosphorus less than 0.30 mg/L-P and total phosphorus less than 1.5 mg/L-P.

This is only one of the numerous tests conducted to examine polymer addition. A very low molecular weight polymers act very similarly to alum or ferric chloride, by neutralizing the charge on the suspended solids and also providing some bridging.



This is only one of the numerous tests conducted to examine optimal mixing and flocculation speeds and durations. Polymer CE 1950 provided very good removal efficiency at moderate dosages.

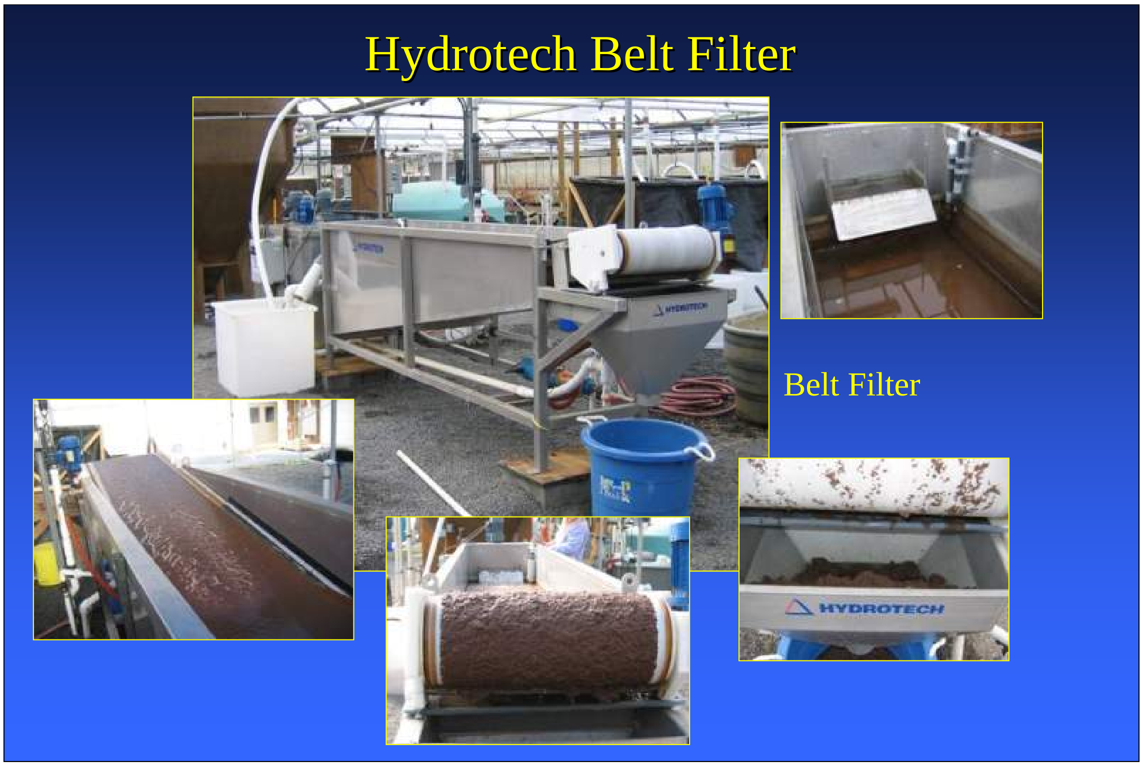
Objectives

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

Hydrotech Belt Filter System

The Hydrotech belt filter, Model HBF537-1H (Figure 1) was purchased from Water Management Technologies, Inc. (Baton Rouge, LA, http://www.W-M-T.com)). The system consisted of two parts, a mixing/flocculation tank and an inclined belt filter.

The mixing tank was separated into four chambers, three with an approximate volume of 0.28 m^3 and one at 0.02 m^3. Total volume of the tank was 0.83 m^3 (Figure 2). The first and last chambers had variable speed mixing impellers for slow mixing and the smaller, intermediate chamber had a fixed, 10 cm diameter, high speed (1080 rpm) impeller for polymer mixing. As the waste stream enters the first chamber, alum was injected with a variable speed, peristaltic pump (Masterflex pump, Model 7524-40) from a reservoir at a dosing rate of 0, 25, 50 75 and 100 mg alum per Liter of waste stream influent. This was accomplished by mixing a concentrated solution of alum, 2000 g alum in 20 L of spring water and with a waste stream flow rate of 40 Lpm, dosing the waste stream at a rate of 0, 10, 20, 30, and 40 mL/ min of alum solution. The 34 cm diameter impeller mixed the alum at 60 rpm with the wastewater stream and began the coagulation process. The fine particles in the wastewater stream were charge neutralized and began to aggregate into small floc. The wastewater stream then flowed over a weir into the smaller chamber, where polymer was injected at the surface, again using a variable speed peristaltic pump from a reservoir at polymer dosages of 0, 5, 10, 15, 20, and 25 mg polymer per Liter of waste stream influent. The polymer used, Hyperfloc CE 1950 was from Hychem, Inc., Tampa, Fl, USA (http://www.hydchem.com), a high degree of cationic charge, very high molecular weight polyacrylamide. The concentrated polymer was first diluted to approximately 0.2% or 2 g polymer in L of spring water, activated by mixing at high speed, and stored in a polyethylene reservoir. At this concentration, the polymer can be stored for about 24 to 48 hrs. A Masterflex pump, Model 7524-40 was used to accurately meter the required dose. A 1080 rpm, fixed speed impeller than mechanically mixes the polymer into the waste stream with a short, vigorous mixing to maximize dispersion of the polymer and forced the wastewater stream down and into the third chamber. There the polymer began the process of aggregation of the small particles and floc. Finally, the wastewater

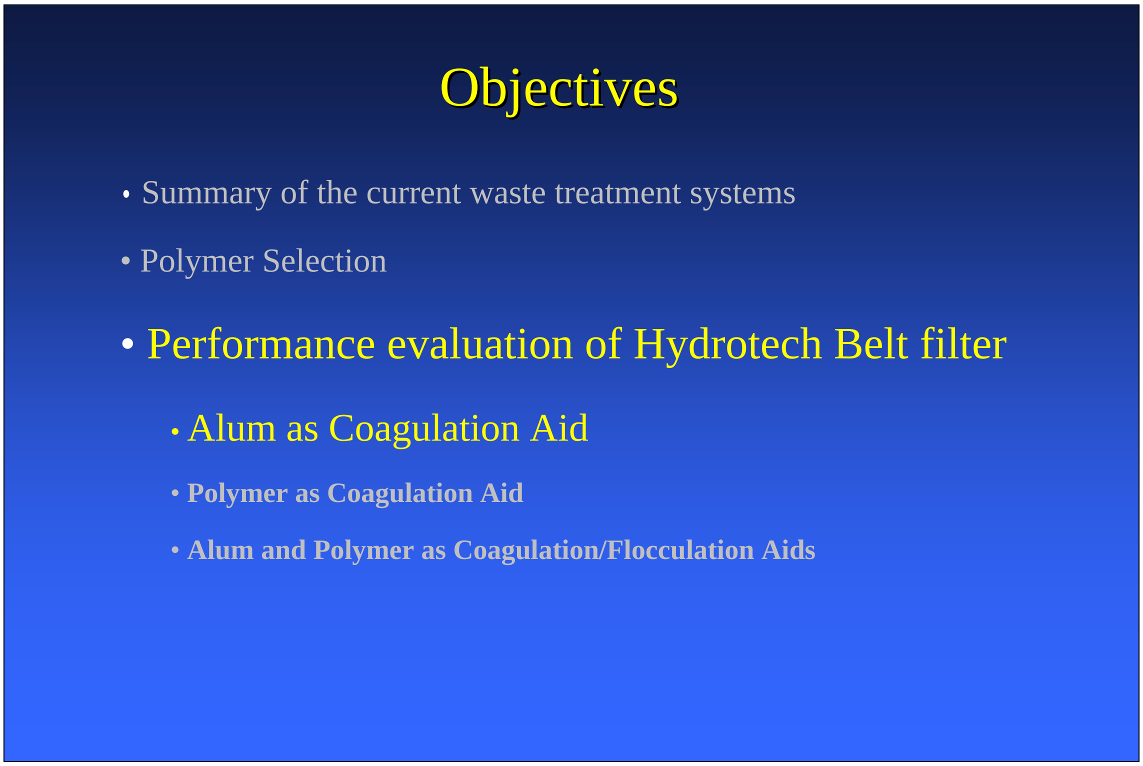


The continuous belt of the inclined belt filter was made of polyester cloth with a mesh size of approximately 120 microns and an angled inclination slope of 10 degrees. As the waste stream flowed onto the belt, the filtrate filters through into the lower sump, and as the belt slowly becomes blocked by sludge, the headloss across the belt filter increases until a level sensor activated a motor which starts the endless band moving. The inclined belt filter then gently lifted the floc out of the water and transported it to the end of the belt where it was scraped off of the belt by means of a firm rubber scraper. A wash water jet spray system then cleaned the belt before it rotates back to the inlet end. During the test trials, the wash water was obtained from a separate clean water source, but could be obtained from the filtrate water in the lower sump. The belt wash water was routed back to the head of the microscreen for further processing. As the belt was self cleaning, belt maintenance was kept to a minimum. In this set-up, the clarified, treated wastewater stream flowed into a pump sump and to an aerobic wastewater treatment pond. The concentrated solids sludge were mixed with straw and as needed transported to a composite facility on site. In the event that the belt filter was unable to process all of the influent flow, a by-pass weir diverted the untreated waste stream back to the head of the microscreen filter.

Hydrotech Belt Filter

During the research trials, the belt filter system was operated in a batch treatment mode. The backwash water from the microscreen filter accumulated in a 400 L HDPE equalization tank until filled, at which point it was pumped to the treatment process. Filling time varied dependent on feed rates and management operations for the two recirculation systems, but usually was approximately one hour. Event counters (Cutler-Hammer E42-2400 Totalizer) and interval timers (Cutler-Hammer E42-DI2475S Elapsed Timer) were installed on the microscreen filter, the sump pump in the equalization tank and the Beltfilter. These allowed determinations of the number of times the microscreen, the sump pump, and the beltfilter turned on and how long they operated. A paddle-wheel flow meter (Signet Totalizer Model #3-5500) measured the total flow and the approximate rate of flow into the coagulation/flocculation tank. Combining the pump on-time and the total flow, allowed calculation of the actual average flow rate through the system.

A typical research trial consisted of setting the individual dosage rates for alum and the polymer, monitoring the system as the sump pump turned on, sampling influent, effluent flow and sludge from the scraper bar near the mid-point of the trial, and estimating effluent discharge rate with a bucket and stop watch. Typically four such trials were conducted per day and on average each dosage rate for alum and polymers were maintained for several days, yielding from nine to twelve separate trials. Finally, an overnight sample was taken from the sludge collection bucket each morning for a composite percent solids analysis.



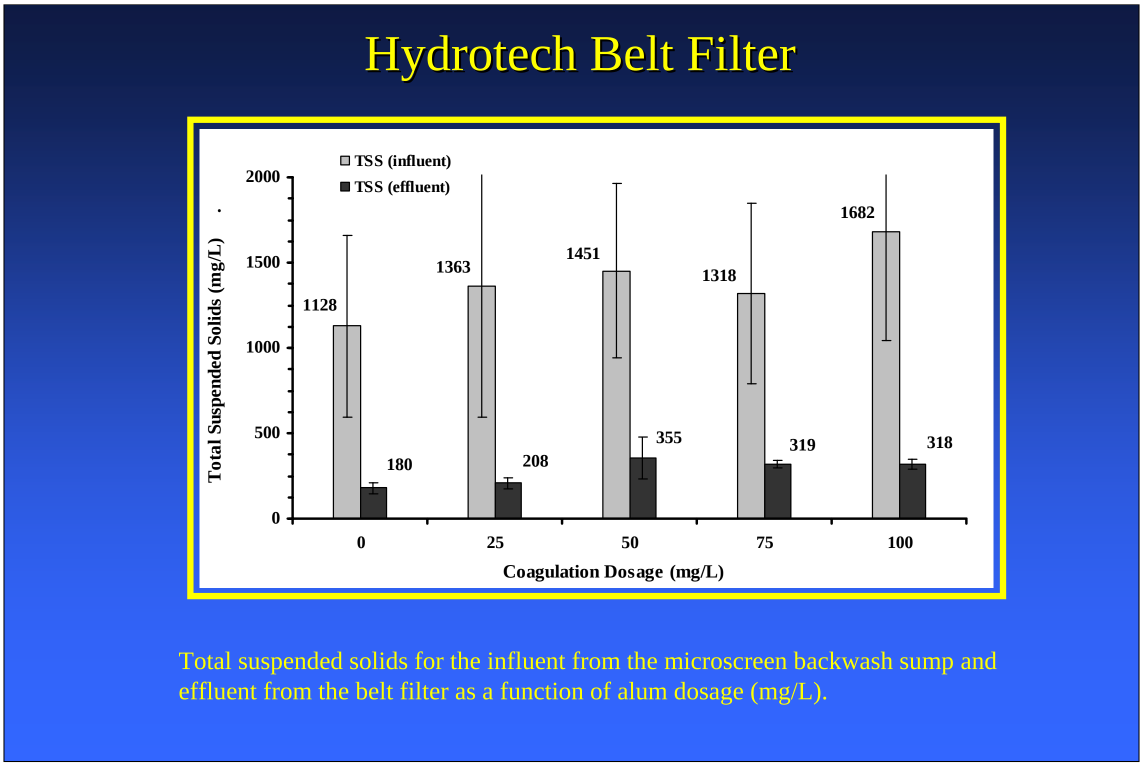
Alum as the coagulation aid

Previous jar test studies with alum demonstrated its excellent performance as a coagulant aid in increasing suspended solids and phosphorus removal for both supernatant off of a settling cone, Ebeling et al. (2003) and for microscreen backwash effluent, Ebeling et al. (2004). In order to determine optimal dosing rate for the belt filter system, a series of tests were undertaken at alum dosages of 0, 25, 50, 75, and 100 mg alum per Liter of waste stream influent. This was accomplished by mixing a concentrated solution of alum (0.2%) or 4000 g alum / 20 L of spring water and based on a waste stream flow rate of 40 Lpm, dosing the waste stream at a rate of 0, 5, 10, 15, and 20 mL/ min of alum solution. A Masterflex pump, Model 7524-40 was used to accurately meter the required dose. Table 3 summarized the results of these tests conducted at 0, 25, 50 75 and 100 mg/L alum dosages for on average of seven separate trials.

Alum

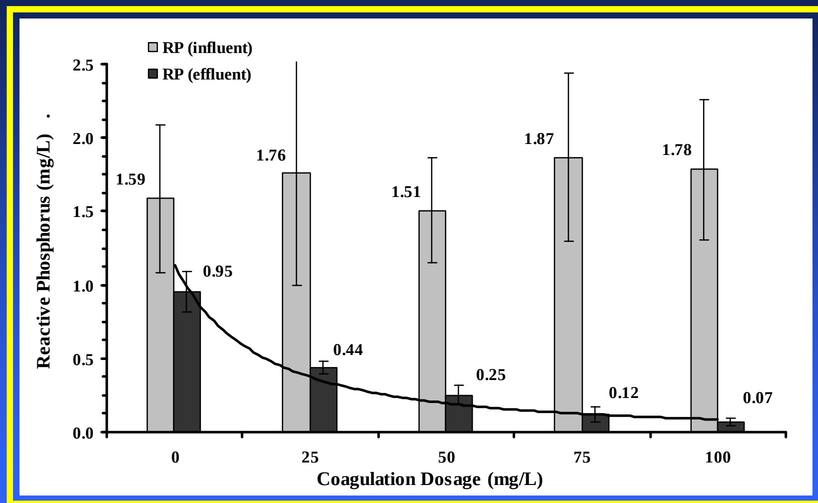
Alum Dosage		pH	Alkalinity (mg/L)	TSS (mg/L) Mean:	TSS (mg/L) StDev:	RP (mg/L-P) Mean	RP (mg/L-P) StDev:
0 mg/L	Influent	7.37	286	1128	534	1.59	0.50
(11)	Effluent	7.39	287	180	33	0.95	0.14
	% Removal			**82%**		**38%**	
25 mg/L	Influent	7.32	303	1363	768	1.76	0.77
(7)	Effluent	7.33	302	208	34	0.44	0.04
	% 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%**	

A Single Factor ANOVA analysis showed no significant difference ($\alpha = 0.05$) for the influent pH and alkalinity of the waste stream, but as can be seen from the table there was an almost consistent linear decline in effluent pH and alkalinity as the dosage rate increased. As previous stated, alkalinity is required for the reaction and if not available must be added at the rate of 0.45 mg/L as $CaCO_3$ for every 1.0 mg/L alum. Although not as apparent at the lower dosage rates, the calculated drop in alkalinity at 100 mg/L alum should be about 45 mg/L, the measured average difference was 46 mg/L. Although not critical for this particular waste stream, for waste stream with low alkalinity (< 50 mg/L) at the higher alum dosage rates some form of alkalinity would have to be added to facilitate this chemical reaction.



The above Figure shows the influent and effluent suspended solids concentration. A Single Factor ANOVA analysis showed no significant difference ($\alpha = 0.05$) for the influent suspended solids concentration, due to the large variation in concentrations tested. This was due to the impact of varying operational and management procedures used during the several months of testing, including tank cleaning, changes in feed rates, and harvesting activities. Overall suspended solids removal was not as high as expected based on the jar tests, with no significant difference between the control and a dosage of 25 mg/L alum. There was a significant difference between the higher alum concentrations, 50, 75 and 100 mg/L, and the control and 25 mg/l alum. The reduced removal rate at high concentrations could be due to the effect of over dosing. Where because of the excess dosage, the alum does not just neutralizing the negative charges on the particulates, but actually adds a net positive charge, creating the same repulsive tendencies between particles as in the initial conditions. Overall, the percent removal of suspended solids for both the control and at 25 mg/L was approximately 82% of the influent TSS concentration.

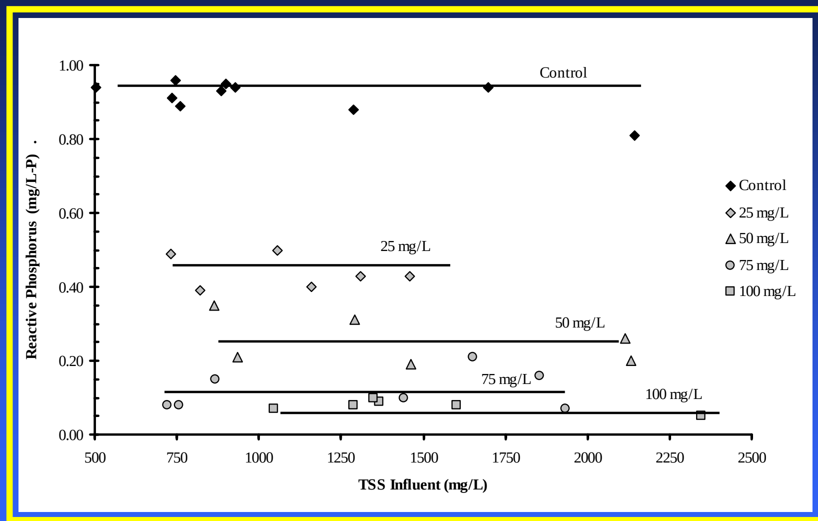
Hydrotech Belt Filter



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

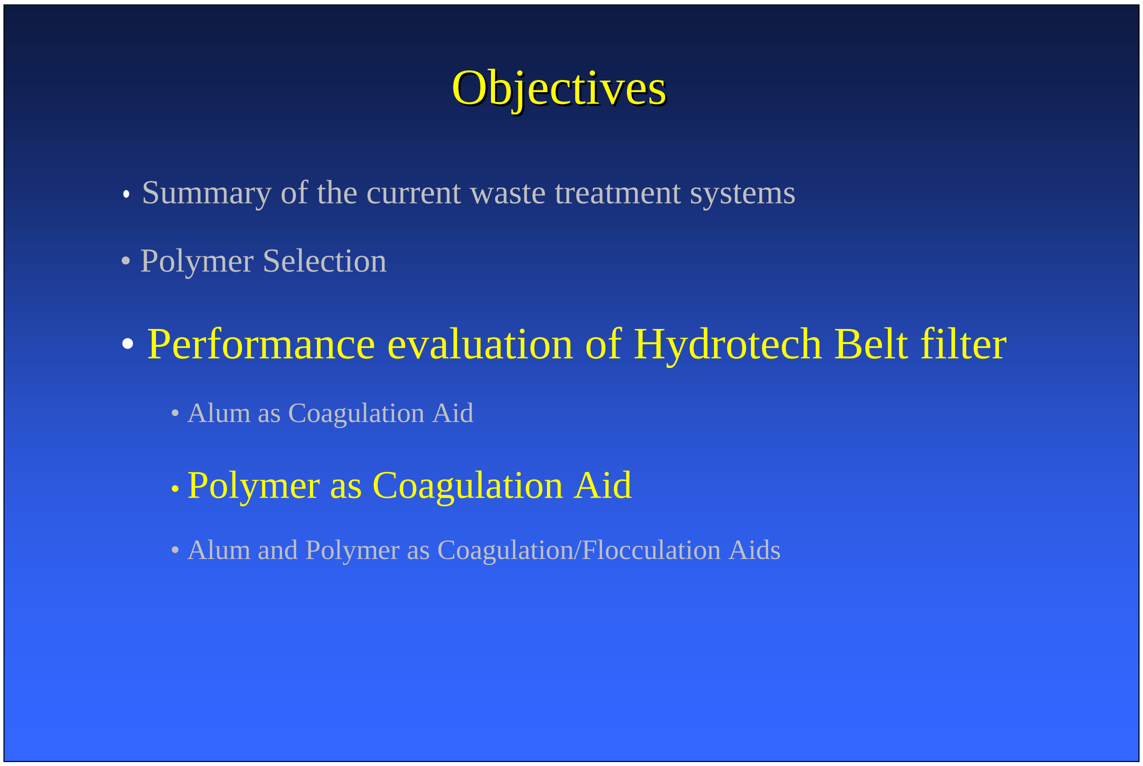
In addition to suspended solids removal, the prime reason for using alum was its sequestering of reactive phosphorus concentration as shown in Eq. 2. The above Figure shows the impact of alum on the reactive phosphorus concentration. A Single Factor ANOVA analysis indicated no significant difference ($\alpha = 0.05$) for the influent reactive phosphorus concentration, but as can be seen above, a significant impact on the effluent concentration. Even at the lowest alum dosage of 25 mg/L, 71% of the reactive phosphorus was removed and 96% at the highest dosage tested, 100 mg/L alum. Thus although only moderately effective for the removal of suspended solids, alum demonstrated an excellent job of sequestering reactive phosphorus.

Hydrotech Belt Filter



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

Finally, The above Figure shows the relationship between the influent suspended solids concentration and the performance of alum in removing reactive phosphorus. Because of different operating procedures, feed rates, harvesting operations, and mixing of the two sources of microscreen backwash effluent, the effluent TSS ranged from as low as 500 to as high as 2500 mg/L. Figure 6 shows that for the control with no coagulation/flocculation aid, the effluent reactive phosphorus was relatively constant at about 0.95 mg/L-P with a s.d. of 0.14 mg/L over the full range of influent TSS concentrations. This was not expected and suggests a constant value of soluble reactive phosphorus over the entire range of influent TSS. As a result of this constant influent reactive phosphorus concentration, the final concentration of the effluent reactive phosphorus remained relatively constant across a wide range of influent TSS, declining as the alum concentration is increased. The implications of this are that a constant alum dosage will be effective over a wide range of influent TSS concentrations for the removal of reactive phosphorus. And for reactive phosphorus removal, the required alum dosage will be determined by the effluent concentration of reactive phosphorus required, based on environmental factors of the receiving system.



Previous jar test studies with a range of commercially available polymers demonstrated their excellent performance as a coagulant/flocculant aid in increasing suspended solids and phosphorus removal for microscreen backwash effluent, Ebeling et al., 2005. Results of these evaluations showed removal of suspended solids was close to 99% via settling, with final TSS values ranging from as low as 10 to 17 mg/L. Although not intended to be used for reactive phosphorus removal, RP was reduced by 92 to 95% to approximately 1 mg/L–P. Dosage requirements were fairly uniform, requiring between 15 and 20 mg/L of polymer.

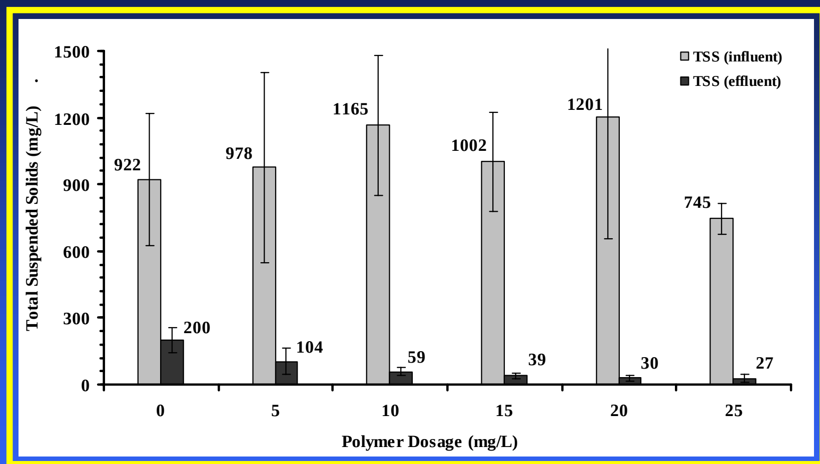
In order to determine optimal dosing rate for the belt filter system, a series of test were undertaken at polymer dosages of 0, 5, 10, 15, 20, and 25 mg polymer per Liter of waste stream influent. The polymer used, Hyperfloc CE 1950 from Hychem, Inc., Tampa, Fl, USA (http://www.hydchem.com), exhibited a high degree of cationic charge, and was a very high molecular weight polyacrylamide. The concentrated polymer was first diluted to approximately 0.2% or 2 g polymer / L of spring water, activated by mixing at high speed, and stored in a polyethylene reservoir. At this concentration, the polymer can be stored for about 24 to 48 hrs. A Masterflex pump, Model 7524-40 was used to accurately meter the required dose. Table 3 summarized the results of these tests conducted at 0, 5, 10, 15, 20, and 25 mg/L polymer dosages for from 8 to 12 separate trials.

Polymer

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

Since there is no chemical reactions involved with the use of polymers, there should be no effect on pH or alkalinity and indeed this was seen with no significant difference in the means of the research trials pH with a paired t-test at $\alpha = 0.05$. As with the previous tests with alum, there was no significant difference in the influent TSS concentrations. There was however, a significant impact on the effluent turbidity and TSS as can be seen in Figure 7. More importantly, there was no significant difference in the highest three polymer dosages (15, 20 and 25 mg/L) for percent removal of TSS averaging approximately 96%, with an effluent TSS concentration of less than 30 mg/L. Thus polymer used alone and at low concentrations was very efficient in removing suspended solids.

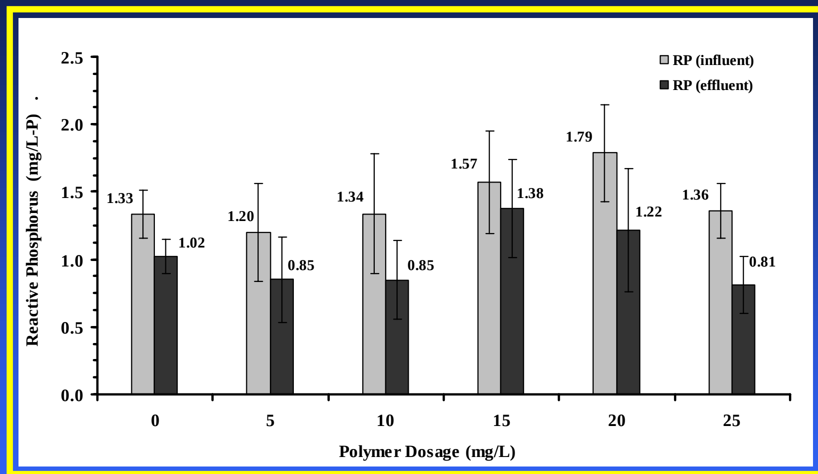
Hydrotech Belt Filter



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).

As with the previous tests with alum, there was no significant difference in the influent TSS concentrations. There was however, a significant impact on the effluent turbidity and TSS as can be seen in Figure 7. More importantly, there was no significant difference in the highest three polymer dosages (15, 20 and 25 mg/L) for percent removal of TSS averaging approximately 96%, with an effluent TSS concentration of less than 30 mg/L. Thus polymer used alone and at low concentrations was very efficient in removing suspended solids.

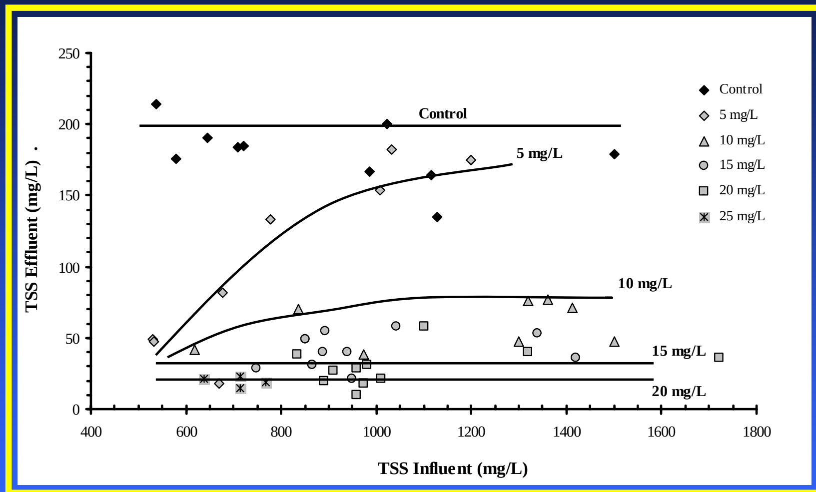
Hydrotech Belt Filter



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

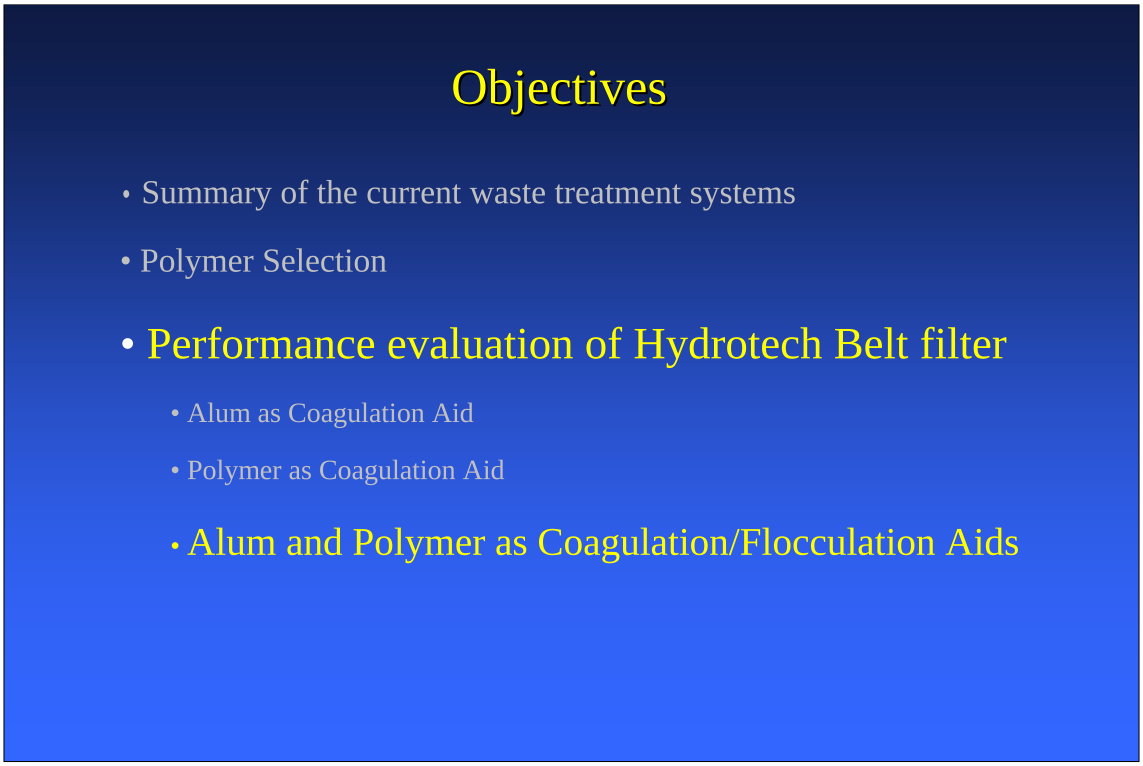
The Figure above shows the removal of reactive phosphorus from the microscreen backwash effluent as a function of the polymer dosage. Except for the 15 mg/L dosage, there was no significant difference between the treatments in percent removal. Although the reactive phosphorus percent removal was lower than seen with the jar test evaluations, the final concentration was approximately the same at about 1.0 mg/L-P. It should be remembered that unlike alum, polymers are not intended for reactive phosphorus removal except by flocculating out small particles.

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).

Finally, the above Figure shows the impact of influent suspended solids concentration on the performance of the polymer. Again because of different operating procedures, feed rates, harvesting operations, etc., the influent TSS ranged from as low as 500 to as high as 2500 mg/L. Figure 8 shows how for the control with no coagulation/flocculation aid, the effluent TSS was relatively constant at about 200 mg/L with a s.d. of 55 mg/L over the full range of influent TSS concentrations. The 5 mg/L polymer dosage demonstrates nicely how the removal rate is a function of influent TSS concentration, where at low TSS there is adequate polymer for both charge neutralization of the particles and flocculation. But as the concentration increases, there is insufficient polymer to completely neutralize all the particles and the removal rate becomes almost equal to the control rate. Correspondingly as the polymer dosage increases, the removal rate improves, until at 10 to 15 mg/L, there is no significant difference between the effluents TSS. Thus for a waste stream with a known and constant TSS value, a fixed dosage of polymer would be required, compared to a higher dosage rate for widely varying influent TSS value.



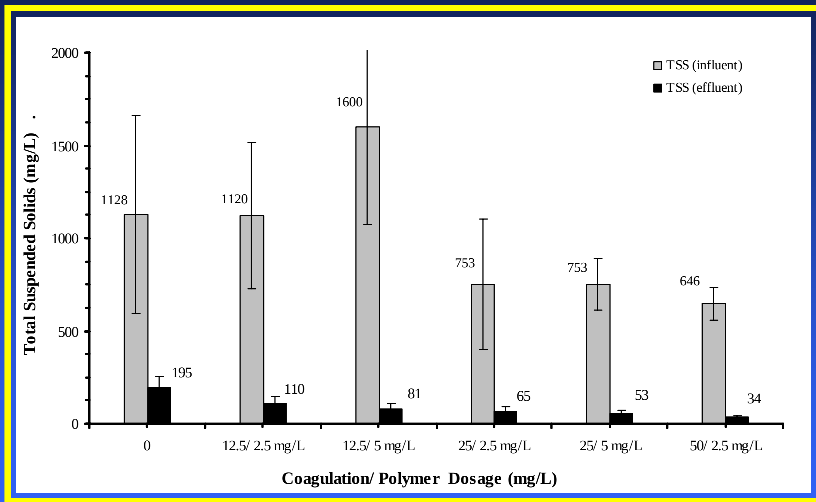
Finally both alum and polymer were used in combination. Previous jar tests had shown that there was a significant reduction in the optimal polymer dosage, when used in combination with alum (Rishel and Ebeling, 2005). In some cases, the required polymer dosages were reduced by as much as a factor of ten, when used in combination with alum to achieve the same suspended solids removal. Based on the jar tests for the polymer used, Hychem, CE 1950, two concentrations of polymer were tested, 2.5 and 5.0 mg/L. A series of tests were then conducted at alum dosages of 12.5, 25, and 50 mg/L and the results are tabulated above.

Alum/ Polymer

Alum/Polymer Dosage		pH	TSS (mg/L)		RP (mg/L-P)	
			Mean:	StDev:	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%**	

As can be seen from the above Table and the following figure, there was a wide variation in the influent suspended solids concentration over the several weeks of the research trial. In terms of the percent removal of suspended solids, there was a significant difference between the treatments, with a synergetic effect of the combination of alum and polymer. As each was increased, the suspended solids concentration decreased, with a final average concentration of only 34 mg/L or 95% removal at the highest combination tested. The important thing to note is that only 2.5 mg/L of Hychem, CE 1950 was used compared to 20 mg/L to achieve the same final suspended solids concentration using this polymer alone.

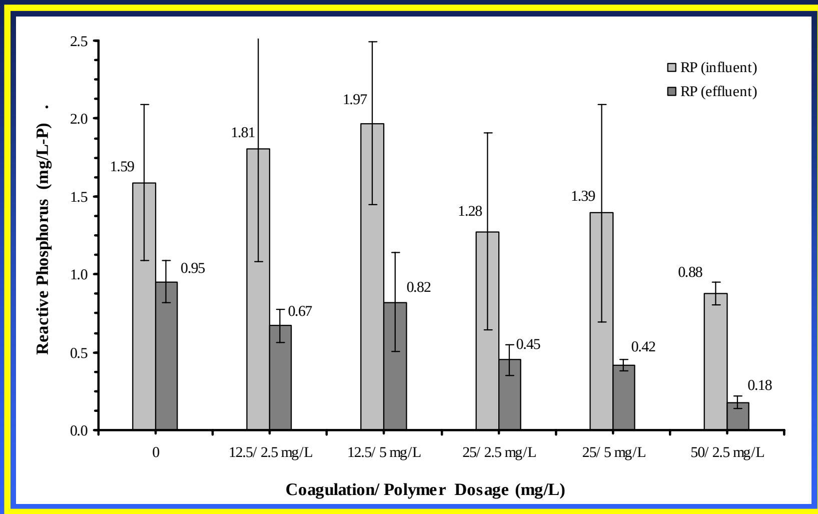
Hydrotech Belt Filter



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).

As was seen when using alum alone and from the above figure, alums impact on suspended solids removal was not as significant as that of the polymer.

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).

What was significant is its impact on reactive phosphorus concentration. As the above figure shows, the concentration of reactive phosphorus steps down with each increase in alum, with no significant impact by the increase in polymer. Thus there was no significant difference between the reactive phosphorus effluent concentration at the alum dosage of 12.5 and polymer dosages of 2.5 and 5.0 mg/L, between the alum dosage of 25 mg/L and polymer dosages of 2.5 and 5.0 mg/L. There was however a significant difference between the three alum dosages, with the highest removal rate and lowest effluent concentration of reactive phosphorus at the highest dosage tested, 50 mg/L. In terms of percent removal of reactive phosphorus, there was no significant difference between all the treatments, except the last, 50 mg/L alum.

Alum:

The average percent solids of the sludge scraped off of the belt by the scrapper bar was 13.2% with a s.d. of 1.1%. This would represent the maximum obtainable from the system, because some of the wash water tends to drain into the solids sump and reduce the overnight composite samples to as low as 5% solids, although this was significantly improved during later test runs. By adding a simple drainage system in the sludge sump, the final percent solids could be substantially improved to 10% solids or higher. Although it needs to be noted, that the final sludge concentration will be to some extent dictated by how the sludge is handled or processed, for example pumped or augured; stored over winter, composted or land applied.

Polymer:

The average percent solids of the sludge scraped off of the belt by the scraper bar was 11.6% with a s.d. of 2.2%, slightly less than with alum alone as a coagulation aid. This would represent the maximum obtainable from the system because some of the wash water tends to drain into the solids sump, although this was substantially reduced by a slight equipment modification so that the overnight composite increased to 9.9% solids.

Alum/Polymer:

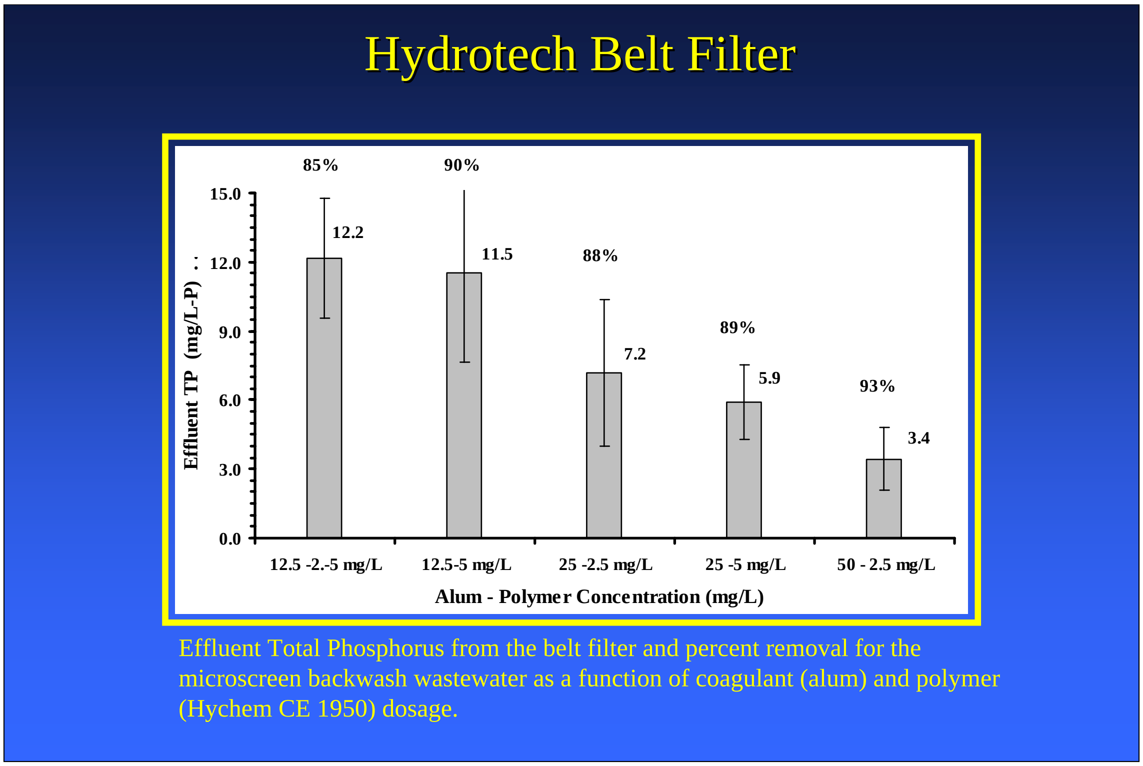
The average percent solids of the sludge scraped off of the belt by the scraper bar was 12.6% with a s.d. of 1.4%, slightly less than with alum or polymer alone as a coagulation aid. This would represent the maximum obtainable from the system because some of the wash water tends to drain into the solids sump, although as

Although the suspended solids and reactive phosphorous in the discharged effluent was the primary focus of this research, several other parameters were evaluated for the combination of alum and polymer trials. These included total phosphorus, total nitrogen, cBOD5, and COD (Table 6). As can be seen Table 6, the combination of alum and phosphorus significantly reduced the total phosphorus concentration in the effluent with a maximum removal efficiency of 93% and for several trials, a discharge concentration less than 2 mg/L-P.

Other Water Quality Parameter

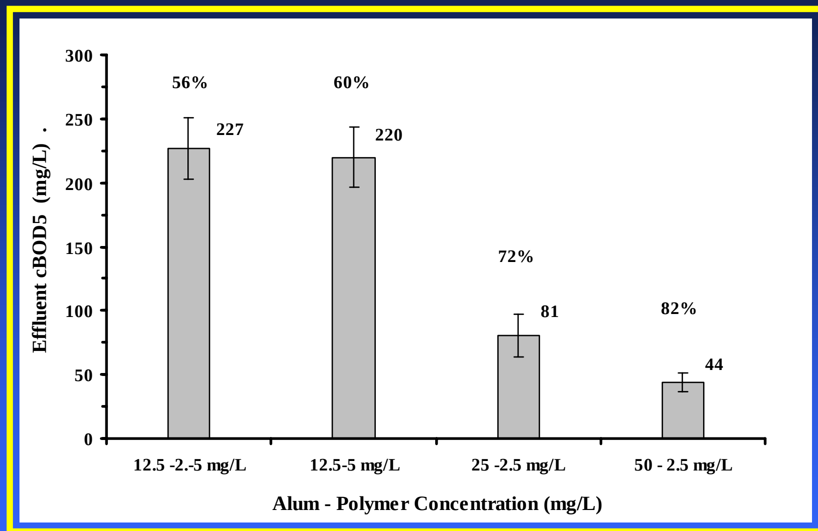
Alum/Polymer Dosage		TP (mg/L-P)		TN (mg/L-N)		$cBOD_5$ (mg/L)		COD	
		Mean:	StDev:	Mean:	StDev:	Mean:	StDev:	Mean:	StDev:
12.5 mg/L / 2.5 mg/L	Influent	95.1	39.9	49.1	20.6	498	89	-----	-----
	Effluent	12.2	2.6	8.5	3.8	227	24	-----	-----
	% Removal	**85%**		**81%**		**56%**			
12.5 mg/L / 5 mg/L	Influent	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%**	

As can be seen from the above Table and the following figure, there was a wide variation in the influent suspended solids concentration over the several weeks of the research trial. In terms of the percent removal of suspended solids, there was a significant difference between the treatments, with a synergetic effect of the combination of alum and polymer. As each was increased, the suspended solids concentration decreased, with a final average concentration of only 34 mg/L or 95% removal at the highest combination tested. The important thing to note is that only 2.5 mg/L of Hychem, CE 1950 was used compared to 20 mg/L to achieve the same final suspended solids concentration using this polymer alone.



The above figure shows how the effluent concentration of total phosphorus was not impacted by the polymer concentration, with no significant difference between the 2.5 and 5 mg/L polymer dosage at a fixed 12.5 mg/L alum dosage, but significant differences as the alum concentration increased. Although not intended for nitrogen removal, total nitrogen in the effluent was reduced by as much as 87% at the maximum dosage tested, with discharge concentrations for some trials of 2.1 mg/L.

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).

The above figure shows the impact of the alum/polymer aids on cBOD5, and again shows that alum played the most significant role. Removal rates for cBOD5 were as high as 82%, with effluent concentrations as low as 35 mg/L. Finally, limited COD data also suggest corresponding reductions as high as 92%.

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

The economics of using polymers look exceedingly good. Assuming that approximately 30% of the feed ends up as suspended solids in the waste stream and that the TSS concentration of the backwash water from the microscreen filter is approximately 1000 mg/L (1 g/l), then each kg of feed generates about 300 L of backwash water. Assuming a treatment of 20 mg/L on average, yields a polymer requirement of only 6 g per kg feed. Cost of the polymers were obtained from the manufacturers and are listed in Table 7. One of the problems with industrial chemicals is that they are usually available only in large quantities, so the smallest size for Ciba Specialty Chemicals is a 450 lb drum and the next size is a 2400 lb tote bin. The smallest quantity available from Hychem is a 5 gallon pail, next a 450 lb drum, a non-returnable tote 2300 lb (275 gallons) and finally the largest quantity available is a railroad tanker. As can be seen from Table 7, the overall operating cost for the polymers investigated is very small in comparison to the cost of the feed.

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%

Alum used alone as a coagulant aid was not as efficient in removing solids (83%) as was expected based on jar tests, but was very efficient in sequestering reactive phosphorus (96%), with effluent concentrations less than 0.07 mg/L-P at 100 mg/L alum. Polymers used alone and at relatively low dosages (15 mg/L) were very efficient in removing suspended solids, with a removal rate averaging 96% and an effluent TSS concentration of less than 30 mg/L. At the optimum dosage of alum and polymer, the Hydrotech Belt Filter System increased the dry matter content of the sludge to approximately 13% solids, and reduced both the suspended solids and soluble phosphorus concentration of the effluent by 95% and 80% respectively. In addition, significant reductions in total phosphorus, total nitrogen, cBOD5, and COD were seen. The combination of coagulation/flocculation aids and the Hydrotech Beltfilter show excellent potential to greatly reduce the volume of solids generated, and significantly reduce the concentration of suspended solids and phosphorus in discharged effluents.

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.

Future work includes additional research trials with other potential polymers and a closer examination and possible modification of the coagulation/flocculation system to improve it performance to match that obtained by laboratory jar tests.

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Questions ?