

Performance Evaluation of Geotextile Tubes

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

Kata L. Rishel
Research Assistant
The Conservation Fund Freshwater Institute

As environmental regulations become more stringent, aquaculture waste management and disposal are becoming increasingly more important in any aquaculture operation. Current technologies used to store and dewater aquaculture solid wastes are often expensive to install, require high maintenance, or have poor treatment efficiencies. Dewatering aquaculture solid waste can increase the options available for disposal. One promising new technology for dewatering aquaculture solid waste is the use of geotextile tubes. Geotextile tubes are porous tubular containers constructed of a woven polyethylene material, which can dewater wastes to over 10% solids in less than a week, and achieve final solids content over 30%. Geotextile tubes have successfully been used to dewater animal wastes, municipal wastewater sludges, hazardous wastes, industrial by-products, and dredge spoil.

A series of tests were conducted to determine the effectiveness of using a Geotube® geotextile bag to dewater solid wastes generated by a recirculating aquaculture system. Effluent wastes generated by these intensive aquaculture systems typically contain 1-2% solids. Jar tests were first used to evaluate the effectiveness of several families of polymers for aquaculture waste effluents. A bench-scale Rapid Dewatering Test Unit (RDT) was used to test a number of parameters, including filtration rates, coagulation/flocculation selection, dewatering time, filtrate quality, and pressure requirements. A series of larger scale tests were also conducted, using a pilot-scale hanging geotextile bag, to further evaluate performance characteristics. Finally, sealed geotextile bags were pumped full under pressure to simulate normal operating conditions with polymer addition. Preliminary results indicate that Geotubes can retain 99% of total suspended solids, almost 90% of nitrogen, and over 60% of phosphorus in the solid wastes added to the Geotube, with a final solids content of over 45% in the retained waste.

Introduction

Problem: 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

Development of improved systems for the disposal and utilization of aquaculture wastes are needed, as enhanced waste management systems will improve the economic viability and sustainability of aquaculture systems. Optimally, aquaculture wastes should be utilized as an environmentally beneficial product. As a result of their high moisture content, the management of solid wastes generated by aquaculture systems presents unique storage and disposal problems. Thickening wastes through dewatering increases the options available for final disposal and reduces the volume needed for storage. In addition, the transportation of aquaculture solid waste can be a major factor in the costs of waste management, since fees are determined on a volume basis. Thus, dewatering sludge reduces the costs of storage and transportation, and increases the options available for disposal.

Technologies currently used to store and dewater aquaculture solid wastes are often expensive to install, require high maintenance, or have poor treatment efficiencies according to geographical location or due to poor management. The two most common methods used to recycle solid wastes from aquaculture facilities are composting and land application. Both methods can be enhanced by dewatering the wastes before utilization. While dewatering aquaculture solid waste can increase the options available for disposal, most dewatering methods result in a total solids content of only 5-10%.

What is a Geotube[®]?

- Geotubes are constructed of Mirafi[®] high strength woven geotextile
- Geotube[®] containers are custom fabricated with seaming techniques that resist pressures during pumping operations.
- High flow rate allows liquid to dewater, while containing solids.



One promising new technology for dewatering aquaculture solid waste is the use of geotextile tubes. Geotextile tubes are porous sealed tubular containers constructed of a woven polyethylene material. Geotextile tubes can dewater wastes to over 10% solids in less than a week, and can achieve final solids content over 30%¹. Geotextile tubes have successfully been used to dewater animal wastes, municipal wastewater sludges; hazardous wastes, industrial by-products, and dredge spoil. Geotextile tubes are cost effective, site-specific, and mobile, require little maintenance, and can be manufactured for high containment volumes.

Geotextile tubes are porous tubular containers constructed of a woven polyethylene material. Geotextile tubes can dewater wastes to over 10% solids in less than a week, and can achieve a final solids content over 30%. Geotextile tubes have successfully been used to dewater animal wastes, municipal wastewater sludge's, hazardous wastes, industrial by-products, and dredge spoil.

Benefits of Geotube® Technology

- Effective high volume containment.
- Efficient dewatering & volume reduction.
- Cost effective.
- No special equipment required.
- Custom site specific fabrication.
- Lower equipment cost.
- Low maintenance.
- Low labor cost.



Geotextile tubes are cost effective, site-specific, mobile, require little maintenance, and can be manufactured for high containment volumes.

Containment



The Geotube ® is pumped with sludge material.

Dewatering



As the liquid escapes from the tube, solid particles are trapped inside.
The process is repeated until the tube is full.

Disposal



Eventually, the solids can be handled as dry material, increasing options for transportation and disposal

Applications for Aquaculture

Freshwater Applications

- Winter Storage of Biosolids
- Composting

Marine Applications Tested by Miratech

- Marine benthic waste
- Marine fresh cage waste
- Hatchery recirculation and pass through waste
- Processing plant blood water
- Biofouling waste from cleaning shellfish cages
- Biofouling toxic waste (copper) from salmon net cleaning

Geotubes® (Ten Cate Nicolon, Commerce, GA) have successfully been pilot-tested in the aquaculture industry for various marine and inland aquaculture wastes. As part of the waste management system at The Conservation Fund's Freshwater Institute, there is a need for intermediate-term (2-6 months) storage of solid wastes, and dewatering processes for incorporation into a waste management system. To this end, it was decided to evaluate the efficiency of dewatering aquaculture solid wastes with Geotubes®; concurrent with the evaluation of other advanced dewatering and treatment technologies. Thus a series of standard jar tests were first used to evaluate the effectiveness of several families of polymers for aquaculture waste effluents. A bench-scale Rapid Dewatering Test Unit (RDT) was used to test a number of parameters with small samples of geotextile material, including filtration rates, coagulation/flocculation selection, dewatering time, filtrate quality, and pressure requirements. A series of larger scale tests were then conducted, using a pilot-scale hanging geotextile bag, to further evaluate performance characteristics. Finally, small scale, sealed geotextile bags were pumped full under pressure with polymer injection to simulate normal operating conditions in an intensive aquaculture recirculation system. This paper presents the results of these tests and preliminary evaluation of operating the geotextile bag under pressure.

Freshwater Institute's Intensive Recirculating Aquaculture Production Systems

- Partial-Reuse Fingerling System
- Recirculating Growout System



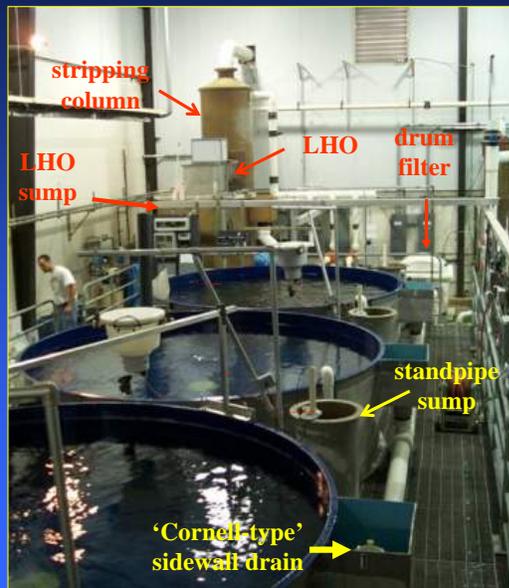
Shepherdstown, WV

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 m³ circular production tank with a maximum daily feed rate of 200 kg of feed per day (Summerfelt et al, 2004b).

Partial-Reuse Fingerling System

Partial-reuse system:

- $\text{NH}_3\text{-N}$ controlled by pH
- pH controlled by CO_2
- Dual drain system
- 1500 lpm recirculation
- bottom drain flow is discharged from system, 12-15% of water flow
- sidewall flow is reused after microscreen filtration
- 45-50 kg feed/day



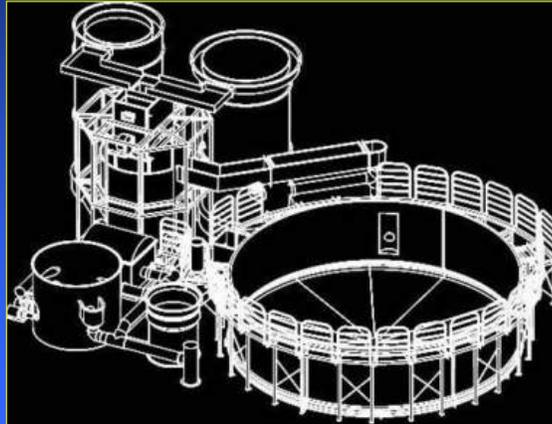
The Freshwater Institute's pilot-scale partial-reuse system, above, consists of three 3.66 m by 1 m deep circular 'Cornell-type' dual-drain culture tanks (Summerfelt, et al., 2000). The 'Cornell-type' dual-drain tank provides for efficient and effective solids removal by concentrating and flushing the 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 make-up water flow rate of from 200 to 300 lpm (50 - 75 gpm).

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 m³ 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 m³ production tank, 9 m in diameter and 2.5 m deep circular 'Cornell-type' dual-drain culture tanks, currently growing arctic char 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 Biofilter™), 2.7 m in diameter and 6.1 m tall. The static sand capacity is approximately 8.5 m³ or a depth of 1.5 m. The Cyclo Biofilter™ had a design TAN assimilation capacity of 200 kg of feed/day or 0.7 kg TAN/m³/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 Arctic char at close 100 kg/m³ 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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Current Aquaculture Waste Management



Pumping Settling Cones



Land Application / Composting



Aerobic Lagoon

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

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 Characteristics

Parameter	Mean
pH	7.43
Temp (Deg. C)	19.4
TP (mg/L - P)	35.3
SRP (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



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Samples for this study were 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. 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. 2002). The second system is a fully-recirculating system consisting of a 150 m³ circular production tank with a maximum daily feed rate of 200 kg of feed per day (Summerfelt et al., In Press). Water quality characteristics of the microscreen backwash effluent are summarized in Table 1. Because of the excess alkalinity of the water at this location i.e. approximately 260 mg/L as Ca CO₃, no alkalinity additions were required in conjunction with alum and ferric chloride treatments.

Objectives

Characterize & Optimize Treatment Capacity

- **Polymer Screening / Evaluation**
 - Rapid Dewatering Test Unit
 - Hanging Bag Tests
 - Pumped Bag Tests
 - Current Research

Polymer Screening / Evaluation

Advantages of Polymers

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

In order to improve the settling characteristics and performance of other filtration technologies, the particle size of the microscreen discharge can be increased by the addition of coagulation/flocculation aids (Ebeling, et al., 2004). Coagulation and flocculation processes with aids such as alum and ferric chloride are standard techniques in the wastewater and drinking water industry for removal of suspended solids. 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 upon:

- 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

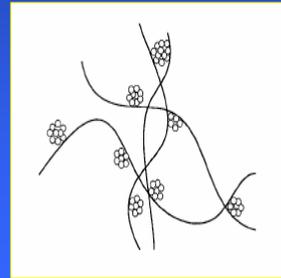
Polymers or polyelectrolytes consist of simple monomers that are polymerized into high-molecular-weight substances (Metcalf and Eddy, 1991) with molecular weights varying from 10⁴ to 10⁶ Daltons. Polymers can vary in molecular weight, structure (linear versus branched), amount of charge, charge type 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, flocculation energy, and 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



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 Screening

Selection is often more of an “art” than a science!

- Ciba Specialty Chemicals Corporation
- Cytec Industries Inc
- Hychem, Inc

Because the chemistry of wastewater has a significant effect on the performance of a polymer, the selection of a type of polymer for use as a coagulant/flocculation aid 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, i.e. most cost effective. This paper presents the results of a series of tests that were conducted to screen a wide range of commercially available polymers and then evaluate the performance of a small subset that showed potential for use with aquaculture microscreen backwash effluent. It by no means intended to be a comprehensive review, but to show the potential of polymers to be used as the sole coagulant/flocculant aid for microscreen backwash effluent.

Three commercial sources of polymers for the wastewater industry were contacted and samples obtained of recommended polymers for aquaculture wastewater. The companies were: Ciba Specialty Chemicals Corporation, <http://www.cibasc.com>; Cytec Industries Inc. <http://www.cytec.com>; and Hychem, Inc., <http://www.hychem.com>. Table 1 lists the individual polymers supplied, the chemical family, charge, molecular weight and form based on data from either product description information or Material Safety Data Sheets.

Polymers Tested

Ciba Specialty Chemicals, 2301 Wilroy Road, Suffolk, VA 23434

Trade Name	Chemical Family	Charge	Molecular Weight
Magnafloc LT 7990	Polyamine	very high degree of cationic charge	very low
Magnafloc LT 7991	Polyamine	very high degree of cationic charge	very low
Magnafloc LT 7992	Organic cationic polyelectrolyte	very high degree of cationic charge	very low
Magnafloc LT 7995	Organic cationic polyelectrolyte	very high degree of cationic charge	very low
Magnafloc LT 7922	Acrylamide polymer or copolymer	low degree of cationic charge	very high
Magnafloc LT 20	Polyacrylamide	degree of nonionic charge	medium
Magnafloc LT 22S	Copolymer of quaternary acrylate salt and acrylamide	low degree of cationic charge	high
Magnafloc LT 25	Copolymer of sodium acrylate and acrylamide	low degree of anionic charge	medium
Magnafloc LT 26	Copolymer of sodium acrylate and acrylamide	medium degree of anionic charge	medium
Magnafloc LT 27	Copolymer of sodium acrylate and acrylamide	medium degree of anionic charge	high
Magnafloc E 30	Polyacrylamide	degree of nonionic charge	high
Magnafloc E 32	Anionic polyacrylamide emulsion	very low degree of anionic charge	high
Magnafloc E 38	Anionic polyacrylamide emulsion	high degree of anionic charge	very high

Celtec Industries, Inc., West Portsmouth, OH

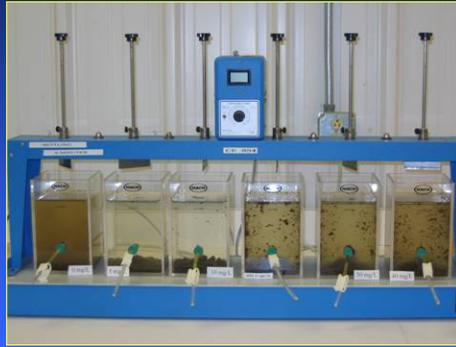
Trade Name	Chemical Family	Charge	Molecular Weight
SuperFloc A-120	Anionic Polyacrylamide	low degree of anionic charge	high
SuperFloc A-130	Anionic Polyacrylamide	medium degree of anionic charge	high
SuperFloc A-137	Polyacrylamide	high degree of anionic charge	high

Hychem, Inc., 10014 N. Dale Mabrey Highway, Suite 213, Tampa, FL 33618

Trade Name	Chemical Family	Charge	Molecular Weight
Hyperfloc CE 834	Cationic polyacrylamide	medium degree of cationic charge	very high
Hyperfloc CE 854	Cationic polyacrylamide	high degree of cationic charge	very high
Hyperfloc CE 1950	Cationic polyacrylamide	high degree of cationic charge	very high

Table 1 lists the individual polymers supplied, the chemical family, charge, molecular weight and form based on data from either product description information or Material Safety Data Sheets

Jar Tests



Determine the optimal:

- dosage
- duration
- intensity

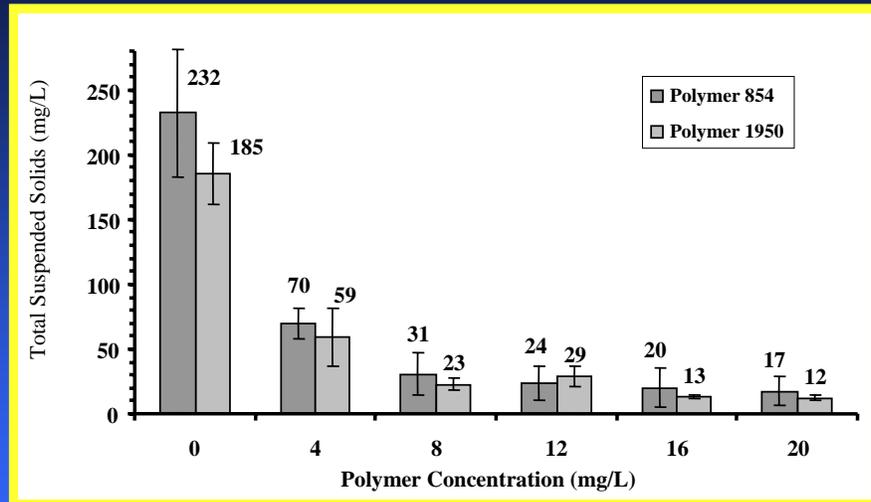
of mixing and flocculation.

For over 50 years, the jar test has been the standard technique used to optimize the addition of coagulants and flocculants used in the wastewater and drinking water treatment industry (ASTM, 1995). Since polymer interactions are very complex, laboratory studies are used to determine the optimal dosage, duration, and intensity of mixing and flocculation. The coagulation-flocculation tests of the polymers were carried out following the standard practice for coagulation-flocculation testing of wastewater used to evaluate the chemicals, dosages, and conditions required to achieve optimum results (ASTM, 1995). Jar tests provide insight into the overall process effectiveness, particularly to mixing intensity and duration as it affects floc size and density, (Lee and Lin, 1999). Samples for jar tests were taken directly from the holding tank receiving the backwash water from two commercial size recirculating production systems growing arctic charr and rainbow 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., 2004). The second system is a fully-recirculating system consisting of a 150 m³ circular production tank with a maximum daily feed rate of 200 kg of feed per day (Summerfelt et al., 2004). Water quality characteristics of the microscreen backwash effluent are summarized in Table 2.

A standard jar test apparatus, the Phipps & Bird Six-Paddle Stirrer with Illuminated Base (Figure 1) was employed for the tests, with six 2-liter square B-Ker2 Plexiglas jars, sometimes called Gator 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.

Stock solutions of the polymer flocculants were used to improve the ease of handling and measuring, and ensure good mixing in the jars. Stock solutions were prepared fresh each day following manufacturer’s recommendations, using either straight dilution or acetone dispersion methods for solid polymers. Simple dilutions of each polymer with spring water to a 0.2% solution by weight were mixed immediately before each test. Normally, the actual test procedures are representative of an existing treatment system, for example a wastewater treatment plant’s mixing, flocculation and settling tanks, in terms of the duration of mixing and flocculation, the mixing speed, and settling time. In this broad screening study, standardized mixing and flocculation speeds and durations were used. For each jar test, the following procedure was followed (ASTM, 1995). Each jar was filled with two liters of microscreen filter backwash sample measured with a graduated cylinder, and the initial temperature recorded. The polymer flocculant dose destined for each jar was carefully measured into syringes using an analytical balance. The multiple stirrer speed was set to the ‘flash mix’ value, i.e. maximum rpm (velocity gradient ~ 400 sec⁻¹), and the test solutions injected into the jars. After the predetermined ‘flash mix’ duration (10 sec), the mixing speed was reduced to the flocculation or ‘slow mix’ value: 20 rpm for 10 minutes. After this time period, the paddles were withdrawn and the floc allowed to settle for 15 min. Samples were then withdrawn from the sampling ports located 10 cm below the water level for analysis.

Results



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

A series of jar tests were used to initially screen each of the eighteen polymers and estimate optimal dosage and percent removal of turbidity and reactive phosphorus. Based on these results, six polymers were chosen for further study (Table 2). Three of the polymers had a very high degree of cationic charge, two have a high degree of cationic charge, and one has a low degree of cationic charge. In addition, three have a very low molecular weight, one has a high molecular weight, and two have a very high molecular weight. No anionic charged polymers were chosen due to their low overall performance. Magnafloc LT 7991, 7992, and 7995 have a very high degree of cationic charge and a low molecular weight so should operate very similarly to coagulants alum and ferric chloride by adsorption-charge neutralization of particles. Hyperfloc CE 854 and CE 1950 have both a high degree of cationic charge and a high molecular weight and should provide both charge neutralization and bridging between particles. Magnafloc LT 22S with a very low degree of cationic charge and a high molecular weight should work primarily by bridging between particles.

Although a wide range of polymers were used, the results show excellent removal efficiencies for all of them, except for LT 22S. Total suspended solids removal was close to 99%, with final TSS values ranging from as low as 10 to 17 mg/L. Although not intended to be used for reactive phosphorus removal, reactive phosphorus was reduced by 92 to 95% by removing most of the TSS in the wastewater to approximately 1 mg/L – P. Dosage requirements were fairly uniform, requiring between 15 and 20 mg/L of polymer. Although LT 22S did not show as good a removal efficiency as the others, 95% of TSS and 92% RP, the requirement of only 2 mg/L of polymer needs to be taken in consideration, in relationship to final discharge limits required.

Removal efficiencies of TSS

Polymer		Raw TSS (mg/L)	Settled TSS (mg/L)	Treated effluent TSS (mg/L)	% removal settling only	% removal settling and polymer
LT 7991	Mean:	830	202	16	76%	98%
18 mg/L	StDev:	60	33	2.3		
LT 7992	Mean:	996	179	17	81%	98%
20 mg/L	StDev:	386	28	0.6		
LT 7995	Mean:	1065	184	15	82%	99%
15 mg/L	StDev:	144	35	2.1		
LT 22S	Mean:	1071	186	55	82%	95%
2 mg/L	StDev:	47	55	20		
CE 854	Mean:	965	232	10	76%	99%
20 mg/L	StDev:	108	49	2		
CE 1950	Mean:	837	185	13	76%	98%
20 mg/L	StDev:	248	23	3		

Although a wide range of polymers were used, the results show excellent removal efficiencies for all of them, except for LT 22S. Total suspended solids removal was close to 99%, with final TSS values ranging from as low as 10 to 17 mg/L. Although not intended to be used for SRP removal, SRP was reduced by 92 to 95% by removing most of the TSS in the wastewater to approximately 1 mg/L – P. Dosage requirements were fairly uniform, requiring between 15 and 20 mg/L of polymer. Although LT 22S did not show as good a removal efficiency as the others, 95% of TSS and 92% SRP, the requirement of only 2 mg/L of polymer needs to be taken in consideration, in relationship to final discharge limits required.

Removal efficiencies of RP

Polymer		Raw	Settled	Treated effluent	% removal	% removal
		TRP (mg/L)	TSS (mg/L)	RP (mg/L)	settling only	settling and polymer
LT 7991	Mean:	14	4.0	1.05	72%	93%
18 mg/L	StDev:	3.3	0.8	0.17		
LT 7992	Mean:	16	3.5	0.93	77%	94%
20 mg/L	StDev:	6.4	0.9	0.15		
LT 7995	Mean:	24.0	4.1	1.09	82%	95%
15 mg/L	StDev:	3.3	0.7	0.26		
LT 22S	Mean:	18.0	3.7	1.38	80%	92%
2 mg/L	StDev:	1.5	1.3	0.45		
CE 854	Mean:	16.8	4.4	0.92	73%	95%
20 mg/L	StDev:	3.5	0.2	0.11		
CE 1950	Mean:	16.3	4.0	0.87	74%	95%
20 mg/L	StDev:	4.4	0.4	0.05		

Table 5 and 6 show the removal efficiencies for TSS and RP for settling alone and also the improvement over settling alone by using a polymer addition. It is interesting to note, that settling alone can remove from 76 to 82% of the TSS and from 72 to 82% of the SRP under jar test conditions, confirming the results of Cripps and Bergheim (2000), who reported 30 – 84% of the phosphorus discharged from aquaculture systems is contained in the solids fraction. The use of polymers improved the removal efficiencies substantially, removing from 71 to 96% of the remaining TSS and 62 to 79% of the remaining TRP.

Objectives

Characterize & Optimize Treatment Capacity

- Polymer Screening / Evaluation
- **Rapid Dewatering Test Unit**
- Hanging Bag Tests
- Pumped Bag Tests
- Current Research

Rapid Dewatering Test Unit



- filtration rates
- chemical selection
- filter media selection
- dewatering time
- filtrate quality
- pressure requirements

Miratech Division-Ten Cate Nicolon has developed a bench-scale Rapid Dewatering Test Unit (RDT) in order to quickly and properly test a number of parameters. They include filtration rates, chemical selection, filter media selection, dewatering time, filtrate quality, and pressure requirements.

UNIT DESCRIPTION

The RDT consists of a 4-inch cylinder with a capacity of one liter of sludge/sediment, the filter media and support, a centimeter scale, filtrate collection and drainage tube, and a tight lid fitted with one air intake valve. The 4-inch translucent cylinder allows observation of the filtration process and provides measurement of the sludge/sediment influent and the captured solids at incremental time periods.

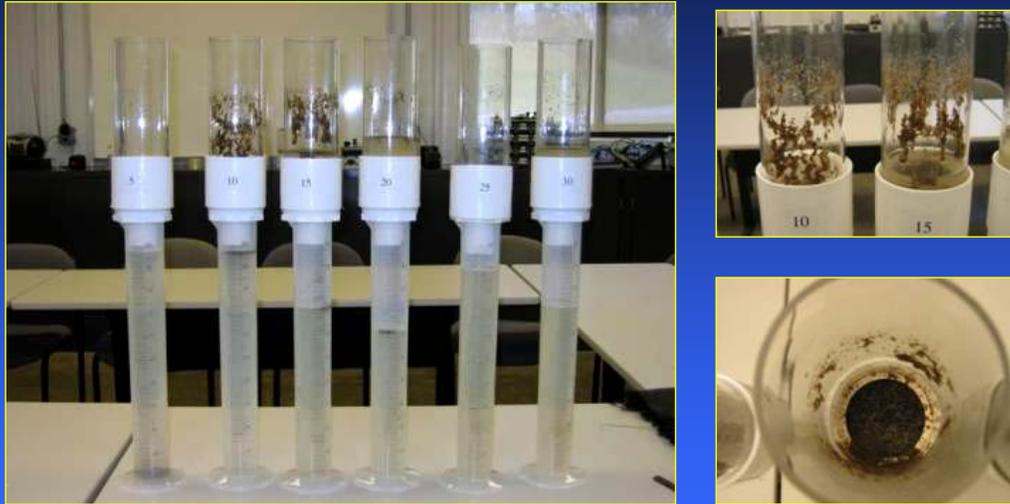
TEST PREPARATION

Prior to starting a filtration test, the following information should be obtained from the attached Material Information

Questionnaire:

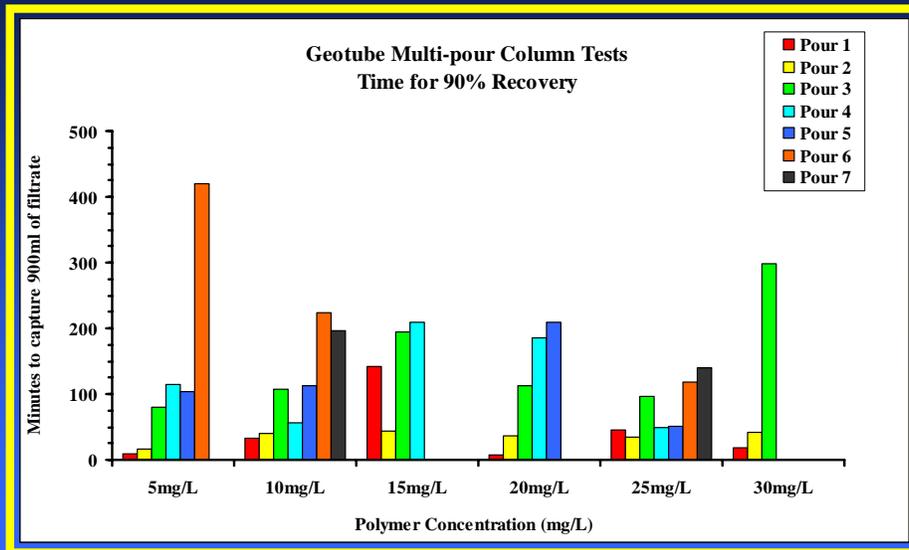
- Type/description of sludge/sediment
- Suspended Solids concentration, % (dry weight basis), Pounds per gallon, Pounds per cubic foot
- pH of sludge/sediment, standard units
- Particle size

Rapid Dewatering Test Unit



A modified version of Miratech Division-Ten Cate Nicolon bench-scale Rapid Dewatering Test Unit (RDT) was used to test a number of parameters, including filtration rates, chemical selection, dewatering time, and filtrate quality. The modified RDT consists of a 4-inch clear acrylic cylinder with a capacity of one liter of sludge/sediment, a 2 inch disk of filter media and support system, and a filtrate collection system. The 4-inch translucent cylinder allows observation of the filtration process and provides measurement of the sludge/sediment influent and the captured solids at incremental time periods. Each test consisted of pouring 1 liter of wastewater that had been treated with CE 1950 polymer at a predetermined dosage using the jar test apparatus. Flux rate through the filter media was monitored by recording the depth of filtrate in the graduated cylinders at set time intervals. Final and initial TSS and turbidity were measured and are shown in Figure 1 as a function of polymer dosage (mg/L). As can be seen, the best performance was for a dosage of 25 mg/L, with a consistently declining filtrate TSS concentration. The time for 90% of the sample to flow through the filter media was also measured and again the 25 mg/L polymer dosage exhibited the quickest and most consistent time. The filter quickly became plugged with fine particles at the lower concentrations and probably with excess polymer at the highest.

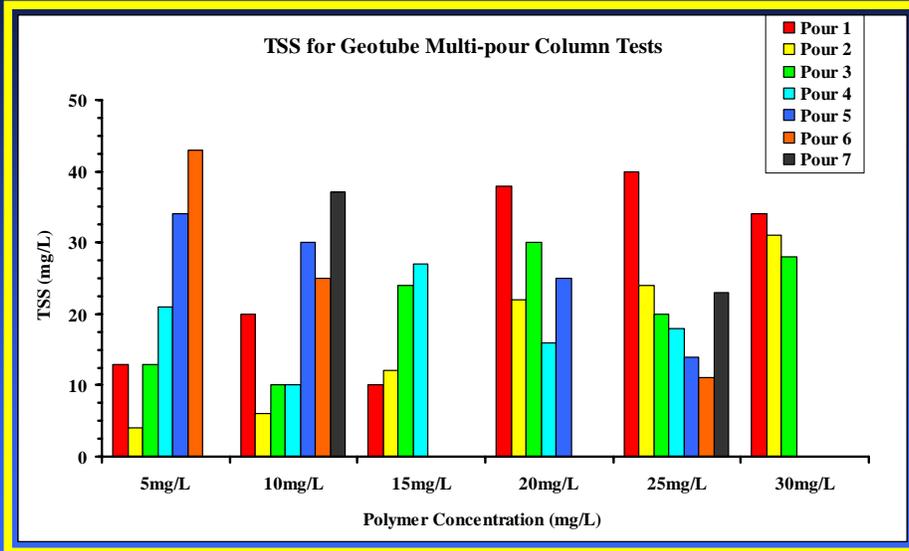
Rapid Dewatering Test Unit



Time for 90% recovery of treated water.

Final and initial TSS and turbidity were measured and are shown in the above figure as a function of polymer dosage (mg/L). As can be seen, the best performance was for a dosage of 25 mg/L, with a consistently declining filtrate TSS concentration. The time for 90% of the sample to flow through the filter media was also measured and again the 25 mg/L polymer dosage exhibited the quickest and most consistent time. The filter quickly became plugged with fine particles at the lower concentrations and probably with excess polymer at the highest.

Rapid Dewatering Test Unit



Effluent TSS from multiple pours.

Objectives

Characterize & Optimize Treatment Capacity

- Polymer Screening / Evaluation
- Rapid Dewatering Test Unit
- **Hanging Bag Tests**
- Pumped Bag Tests
- Current Research

The hanging bag test is a method used to determine the flow rate of suspended solids through a geotextile container with polymer additions.

Hanging Bag Tests



Proposed ASTM Standard Method

- Index test for performance evaluation
- Means of evaluating geotextile containers
- Determining amount of sediment retained
- Determining flow rate for specific conditions



A series of tests, using a pilot-scale hanging geotextile bag, were conducted to determine the effectiveness of using a Geotube® geotextile bag to dewater ASW generated by microscreen-filtration of recirculating coolwater aquaculture system (RAS) effluent. Aquaculture solid wastes generated by the RAS (Summerfelt et al. 2004) typically consist of 1-2% solids (Table 1). Treatment capacity and efficiency of the Geotube for dewatering and treating ASW was determined, as was the length of time required for dewatering both with, and without polymer addition. As part of ongoing waste management research at TCFFI various polymers have been screened for their effectiveness as flocculation aids with ASW using standard jar test procedures (Ebeling, et al., 2004). Jar tests are used to determine optimal dosage rates and mixing and flocculation energy requirements. Turbidity was used as an indicator of the solids concentration in the waste treated. Out of this research, two polymers emerged as being potentially effective for dewatering ASW (Figure 1): Magnafloc® LT-7922 (Ciba Specialty Chemicals, Suffolk, VA) – very low molecular weight with a very high degree of cationic charge; and Hyperfloc® CE-1950 (Hychem, Tampa, FL) – high charge, very high molecular weight.

Test method:

The time and amount of sediment that flows through the geotextile container collected at given time intervals is measured. The amount of sediment passing the geotextile container is determined as the total suspended solids and the flow rate calculated from these values.

Geolon® GT500 is composed of high-tenacity polypropylene yarns, which are woven into a network network such that the yarns retain their relative position. GT500 is inert to biological degradation and resistant to naturally encountered chemicals, alkalis, and acids.

Three tests (No polymer, Polymer LT-7922, Polymer CE-1950) were conducted using a Geotube® bag (0.61 m wide, 1.52 m high, flat dimensions) suspended over a filtrate collection tank. The Geotube bag used in these tests was manufactured of Geolon GT-500 polypropylene yarn. The apparent opening size of this material is 0.425 mm and the hydraulic transmissivity is 814 L/min/m². A new bag was used after each test. During each test the bag was filled sequentially 5-6 times with \approx 140 L of wastewater through an 18 m long pipeline via a submersible pump in the microscreen filter backwash sump. Flow rate into the bag ranged from 38 – 114 Lpm and composite influent and filtrate samples were collected during each fill. One week after the last fill, the bag was opened and a composite sludge sample collected for analysis. During each polymer test, the polymer was injected into the pipeline via a peristaltic pump located approximately midway along the pipeline and mixed using a static inline vortex mixer. Concentrations of total suspended solids, total nitrogen, total phosphorus, and soluble reactive phosphorus were measured using standard methods

Hanging Bag Tests - Methods

- Geotube charged with \cong 140 liters of drum filter backwash
- Influent and effluent samples collected during each fill (Each bag typically filled six times)
- One week after last fill bag was opened and sludge sample collected



Three tests (No polymer, Polymer LT-7922, Polymer CE-1950) were conducted using a Geotube® bag (0.61 m wide, 1.52 m high, flat dimensions) suspended over a filtrate collection tank. The Geotube bag used in these tests was manufactured of Geolon GT-500 polypropylene yarn. The apparent opening size of this material is 0.425 mm and the hydraulic transmissivity is 814 L/min/m². A new bag was used after each test. During each test the bag was filled sequentially 5-6 times with \cong 140 L of ASW through an 18 m long pipeline. The ASW was transferred through the pipeline via a submersible pump located in a sump collecting ASW from a microscreen filter. Immediately before each filling, the pipeline was primed with ASW in order to ensure accurate volume measurement, and that the ASW was fresh. Flow rate of ASW into the bag ranged from 38 – 114 Lpm. Composite influent and filtrate samples were collected during each fill. Filtrate samples were collected after filtration was complete. One week after the last fill, the bag was opened and a composite sludge sample collected for analysis. During each polymer test, the polymer was injected into the pipeline via a peristaltic pump (Cole-Parmer, Vernon Hills, IL) located approximately midway along the pipeline. Injected polymer was mixed using a static inline vortex mixer (Koflo, Cary, IL). Concentrations of total suspended solids, total nitrogen, total ammonia nitrogen, total phosphorus, and soluble reactive phosphorus were measured in the raw ASW and the filtrate from the bag along with total solids, total nitrogen, and total phosphorus in the dewatered ASW (APHA, 1998).

Hanging Bag Tests - Methods

Compared effectiveness with and without polymers

- LT-7922 (Ciba) (23 mg/L) - a **very high degree** of cationic charge , **very low molecular weight**, organic polyelectrolyte flocculant.
- CE-1950 (Hychem) (31 mg/L) - **high degree** of cationic charge, **very high molecular weight** polyacrylamide flocculant.

Three tests (No polymer, Polymer LT-7922, Polymer CE-1950) were conducted using a Geotube® bag (0.61 m wide, 1.52 m high, flat dimensions) suspended over a filtrate collection tank.

Hanging Bag Tests - Flux Rate

Without Polymer

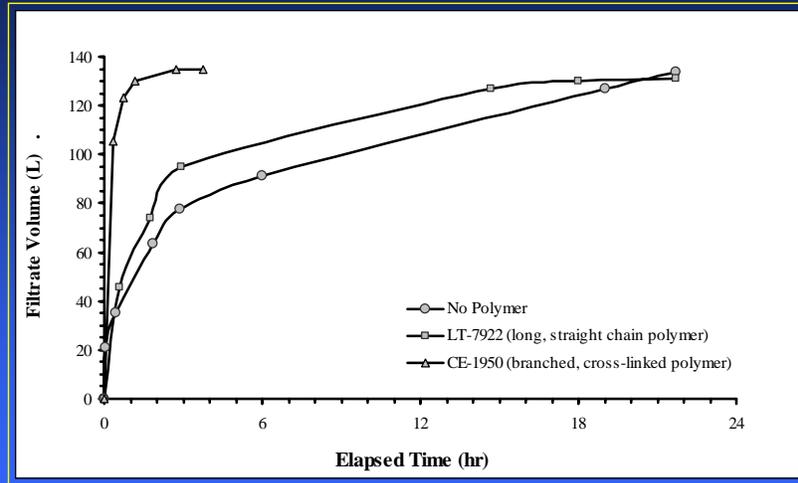


With Polymer (CE-1950)



The filtration rate of ASW through the Geotube varied by treatment (Figure 2). The average time required for all of the ASW pumped into the Geotube to be filtered ranged from 4 h (CE-1950) to 4 d (No Polymer). The particular characteristics of the CE-1950 polymer allowed for rapid filtration through the Geotube. The branched chains of the CE-1950 polymer provide pathways for water to migrate through and out of the flocculated solids, whereas a long, straight chain polymer (such as LT-7922) creates flocculated solids that are more gelatinous and impervious to water in essence binding up water that would be released otherwise by the CE-1950 cross-linked flocculant. As evident in the No Polymer and LT 7922 treatments, lack of these characteristics caused filtration to occur very slowly. Filtration of pure water through the Geotube material is instantaneous at flow rates used in these experiments.

Hanging Bag Tests - Flux Rate



The above figure shows the filtration rate through the Geotube for the three polymers tested. The average time required for the total volume of wastewater to be filtered ranged from 4 h (CE-1950) to 4 d (No Polymer). The particular characteristics of the CE-1950 polymer allowed for rapid filtration through the Geotube. The branched chains of the CE-1950 polymer provide pathways for water to migrate through and out of the flocculated solids, whereas a long, straight chain polymer i.e. LT-7922, creates flocculated solids that are more gelatinous and impervious to water in essence binding up water that would be released otherwise by the CE-1950 cross-linked flocculant. As evident in the No Polymer and LT 7922 treatments, lack of these characteristics caused filtration to occur very slowly.

Hanging Bag Tests - TSS

Parameter	No	Polymer LT-7922 (23 mg/L)	Polymer CE-1950 (31 mg/L)
	Polymer		
Total Suspended Solids (mg/L)			
In	1375	1625	1170
Out	202	283	10.0
Percent Reduction	85.3%	82.6%	99.1%
Residual Solids (%)	26.8%	15.9%	46.0%

Experimental results (Table above) for the two polymers tested showed considerable difference in their performance with the CE-1950 polymer demonstrating excellent removal of solids (99%) with high residual solids (46%). All treatments resulted in residual solids of over 15%. The fact that the LT-7922 treatment had the lowest residual solids content is believed to have occurred as a result of water being retained in the flocculated solids.

Hanging Bag Tests – PO₄-P

Parameter		No	Polymer	Polymer
		Polymer	LT-7922 (23 mg/L)	CE-1950 (31 mg/L)
Soluble Reactive Phosphorus (mg/L - P)				
	In	16.5	19.1	20.6
	Out	11.7	7.1	7.9
	Percent Reduction	29.3%	62.6%	61.5%
Total Phosphorus (mg/L - P)				
	In	20.3	20.3	44.7
	Out	14.5	12.3	5.8
	Percent Reduction	28.8%	39.5%	86.9%

Both polymers substantially improved the removal of Soluble Reactive Phosphorus (62%), but showed differences in Total Ammonia Nitrogen (TAN) removal rates, 11% for the LT-7922 and 63% for the CE-1950. The CE-1950 polymer removed over 85% of both Total Nitrogen and Total Phosphorus compared to 79% (TN) and 40% (TP) for LT-7922. The No Polymer treatment resulted in phosphorus reductions of less than 30% and a Total Nitrogen reduction of 36%. The No Polymer treatment resulted in a net increase in TAN in the filtrate. The low TAN removal rates for the No Polymer and LT-7922 treatments were likely an artifact of the extended interval between the filling of the geotube and collection of the filtrate sample as this would allow for ammonification of organic nitrogen in the ASW and filtrate. The above results demonstrate the importance of using the appropriate polymer for a particular waste and the need to evaluate a wide range of polymers for the specific waste stream.

Hanging Bag Tests – Nitrogen

Parameter		No	Polymer	Polymer
		Polymer	LT-7922 (23 mg/L)	CE-1950 (31 mg/L)
Total Nitrogen (mg/L - N)				
	In	87.5	178	75.3
	Out	55.7	38.0	7.6
	Percent Reduction	36.4%	78.7%	89.9%
Total Ammonia Nitrogen (mg/L - N)				
	In	13.1	11.5	11.5
	Out	30.2	10.3	4.3
	Percent Reduction	-130%	10.9%	63.0%

Both polymers substantially improved the removal of Soluble Reactive Phosphorus (62%), but showed differences in Total Ammonia Nitrogen (TAN) removal rates, 11% for the LT-7922 and 63% for the CE-1950. The CE-1950 polymer removed over 85% of both Total Nitrogen and Total Phosphorus compared to 79% (TN) and 40% (TP) for LT-7922. The No Polymer treatment resulted in phosphorus reductions of less than 30% and a Total Nitrogen reduction of 36%. The No Polymer treatment resulted in a net increase in TAN in the filtrate. The low TAN removal rates for the No Polymer and LT-7922 treatments were likely an artifact of the extended interval between the filling of the geotube and collection of the filtrate sample as this would allow for ammonification of organic nitrogen in the ASW and filtrate. The above results demonstrate the importance of using the appropriate polymer for a particular waste and the need to evaluate a wide range of polymers for the specific waste stream.

Objectives

Characterize & Optimize Treatment Capacity

- Polymer Screening / Evaluation
- Rapid Dewatering Test Unit
- Hanging Bag Tests
- **Pumped Bag Tests**
- Current Research

Pumped Bag Tests



The normal operating procedure for geotextile bags is to pump them full with sludge and allow the sludge to slowly dewater and drain out of the porous bag. This works well with sludge that has a high solids content (10 to 30% solids), but initial tests showed that for the solids content of aquacultural wastes (0.1 to 1% solids) insufficient solids were deposited in the bags during each fill/drain cycle.

Pumped Bag Tests



These tests were conducted with small bags, specially made with dimensions of 2 ft x 4 ft with a standard 2 in flange inlet.

Pumped Bag Tests



Test procedures were similar to the hanging bag tests with the addition of a paddlewheel flow meter and totalizer that allowed accurate dosing of each bag. For each test, approximately 75 L of wastewater was pumped into three bags at 18 Lpm flow rate. The bags were then allowed to settle and the process repeated

Pumped Bag Tests



Polymer reservoir



Flow Meter



Vortex Mixer



Manifold



Pressure Gauge

Pumped Bag Tests



Pumped Test

Effluent - Influent

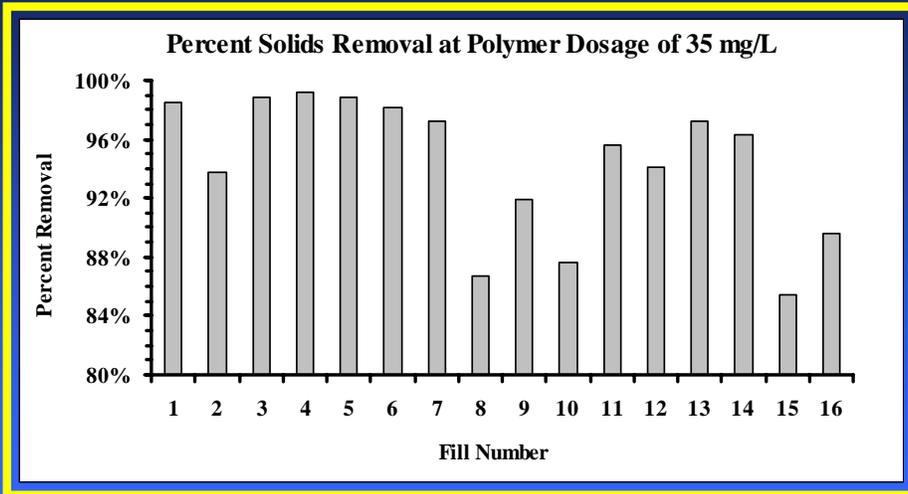


Pumped Bag Tests

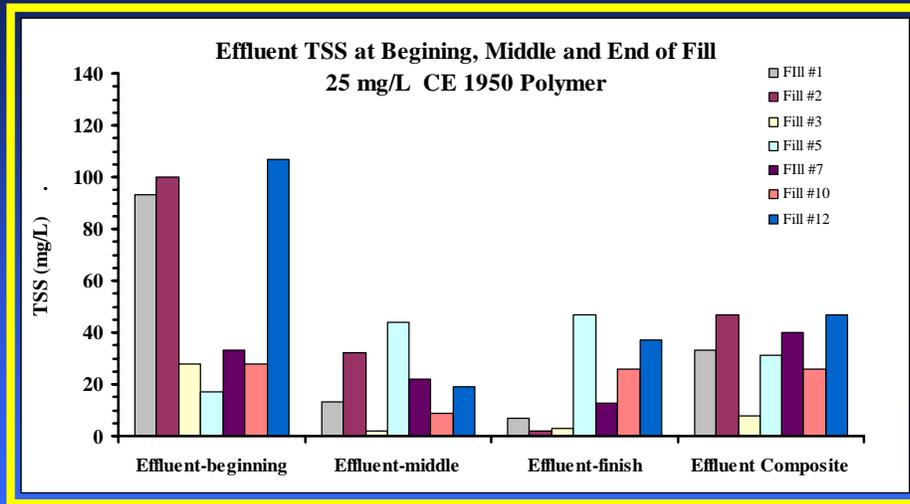
Polymer Dose (mg/L)	Influent TSS (mg/L)	Effluent TSS (mg/L)	Total Flow (L)	Flow Rate (lpm)	Actual Dosage (mg/L)	Total Solids (g)	Solids Removal (g)	Percent Capture (%)
38	772	38	1259	19.2	39	963	918	94.3%
	302	25		3.9	5			5%
25	829	34	989	18.6	28	734	704	95.8%
	316	21		2.4	4.1			3%
15	863	25	336	16.7	19	297	289	96.9%
	183	15		2.8	4			2%

Table 4 summarizes this series of tests conducted at three different polymer dosages, 38, 25, and 15 mg/L of polymer CE 1950. Figure 2 shows the influent and composite effluent wastewater. Excellent removal of solids was seen at all the polymer dosages with no significant difference in percent capture.

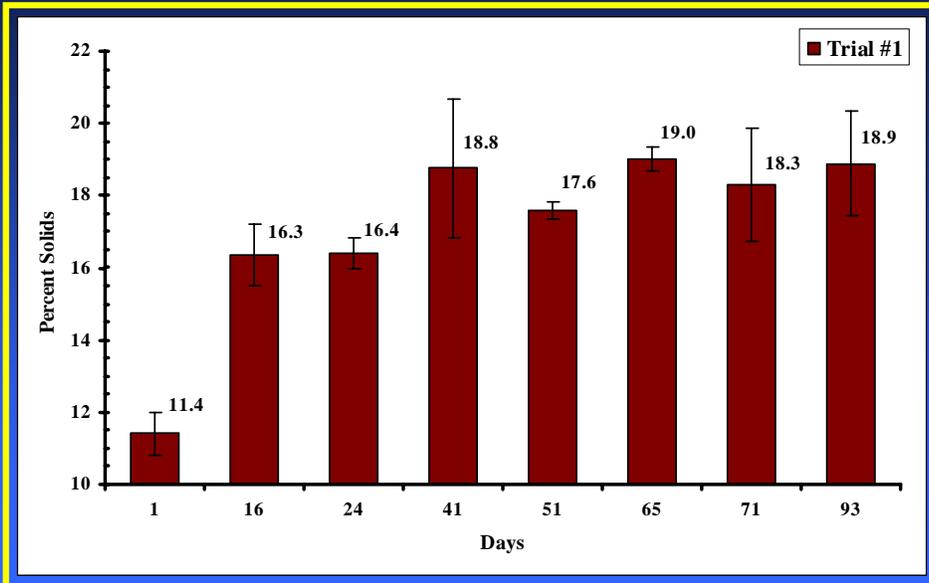
Pumped Bag Tests



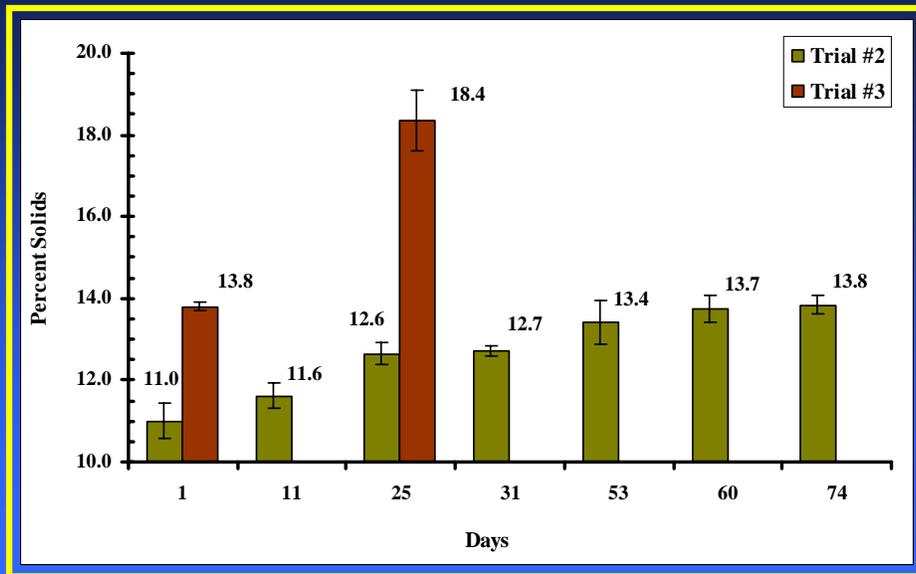
Pumped Bag Tests



Percent Solids vs Time



Percent Solids vs Time



Current Research



- Three month pilot-scale project.
- Alum / Polymer dose based upon previous research.
- Wastewater supplied to three geobags on an hourly basis.

Current Research – Large Geobags



- Each of the three bags were operated at a mean hydraulic loading rate of 58.7 Liters/day/m² geotextile material.
- Solids pumped to the bags for 0.5 minutes each hour (24/7).

Wastewater Source

- Inlet samples (3) taken from sampling ports prior to addition of alum/polymer.
- Temp: 17.0 ± 0.3
- pH: 7.56 ± 0.02
- Alkalinity: 303 ± 10
- DO: 7.6 ± 0.3
- Inline mixers used after alum/polymer addition

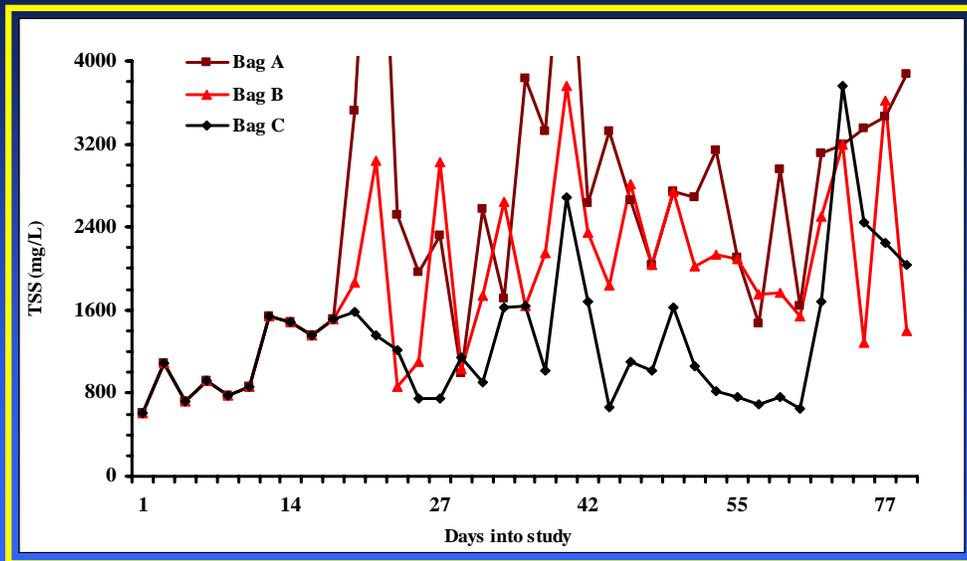


Results

	Bag Influent	Bag Effluent	% Removal
TSS (mg/l)	1875 ± 811	98 ± 25	93.0 ± 3
Total Phosphorus (mg/l)	40.6 ± 16	12.7 ± 4.1	65 ± 12
Dissolved Reactive P (mg/l)	1.1 ± 0.7	10.8 ± 3.2	-1145 ± 574
Total Nitrogen (mg/l)	63.8 ± 25	37.9 ± 12	32 ± 24
TAN (mg/l)	1.7 ± 0.6	28.1 ± 9.9	-1587 ± 490
cBOD ₅ (mg/l)	517 ± 241	309 ± 80	47 ± 15

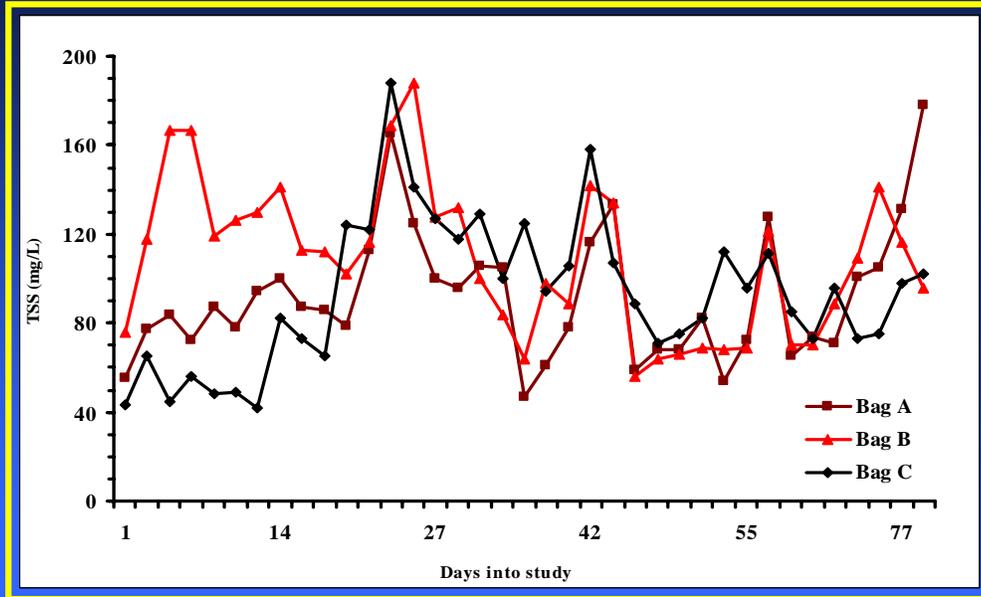
36 Samples over 3 months

Results – TSS Effluent



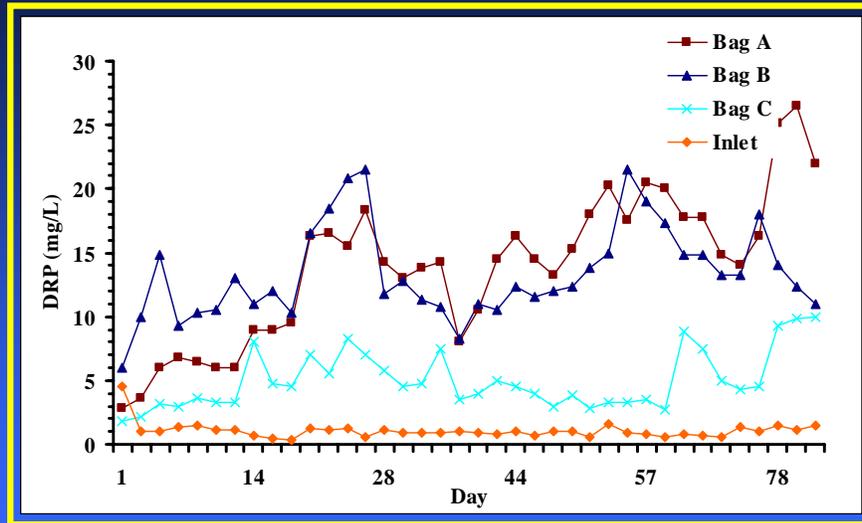
Indicates consistent removal of TSS over time.

Results – TSS Effluent



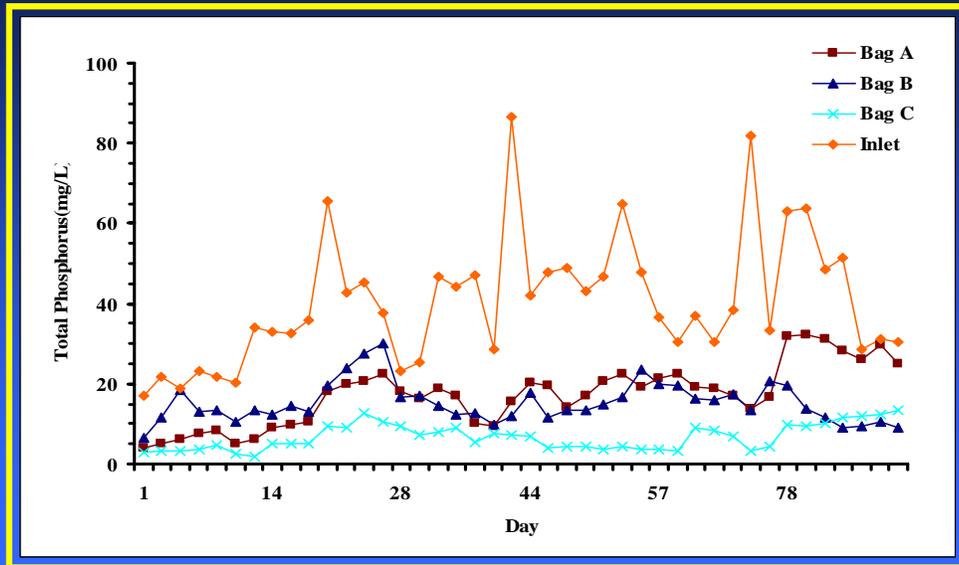
Indicates consistent removal of TSS over time.

Results – Reactive Phosphorus

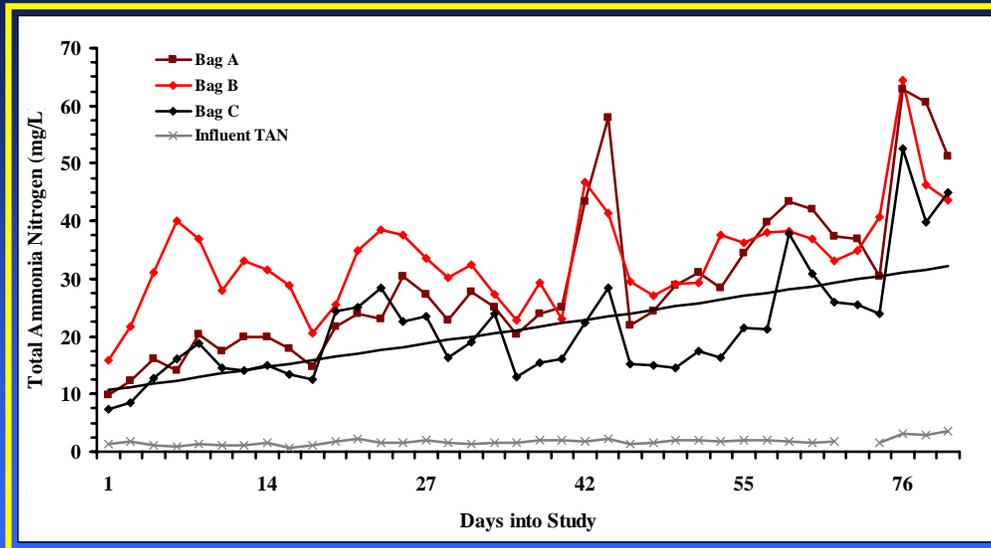


- Solids capture in geobags results in break down of proteins, release of TAN, and subsequent mineralization of phosphorus.

Results – Total Phosphorus

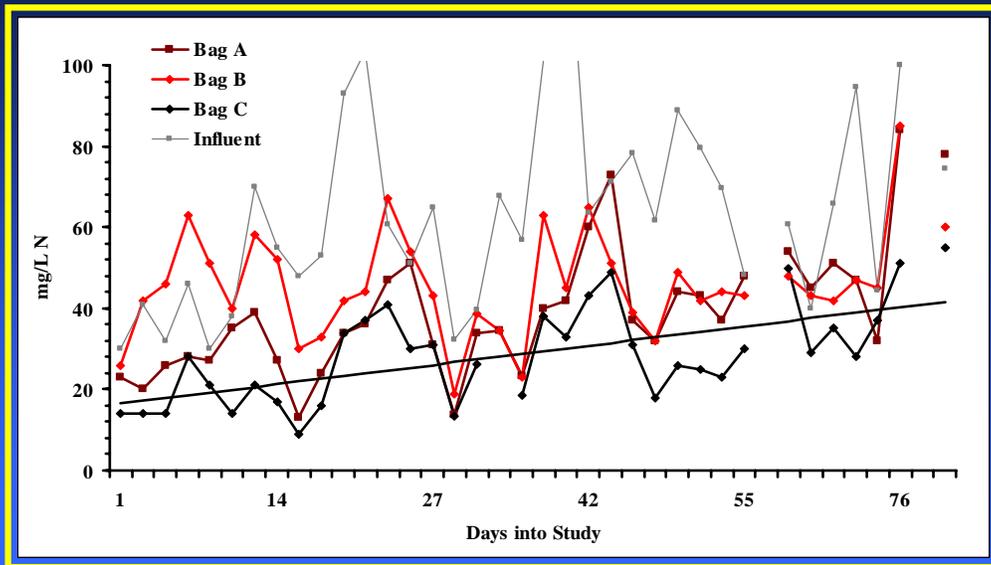


Results – Total Ammonia Nitrogen



- Solids capture in geobags results in break down of proteins and subsequent release of TAN.

Results – Total Nitrogen



Results – Other Parameters

	Bag Influent	Bag Effluent	% Removal
COD (mg/l)	1889 ± 723	566 ± 119	66 ± 11
pH	7.55	7.20	
Alkalinity (mg/L)	303	363	
Temperature (Deg C)	16.8	19.6	

Conclusions

- Geotextile Bags hold excellent potential for treatment of aquaculture effluents
- With appropriate polymers, Effluent TSS can be less than 30-100 mg/L
- Significant impact on total reactive phosphorus and Total Ammonia Nitrogen concentrations
- Residual solids concentration high

4. Conclusions

Next Steps...

- Economic Analysis
- Process Optimization
 - Polymer Use
 - Coagulants
 - Loading Rate



Future work at TCFFI will include further testing of a wide range of polymers to characterize their performance with ASW. Several coagulation aids will also be explored for their ability to remove nutrients and suspended solids. A series of tests will be conducted to examine loading rates and management practices on overall Geotube performance. At some point, the residual solids will be field tested to determine compostability. Finally, as part of an on-going aquaculture waste management research program, TCFFI will be comparing the Geotube to other dewatering technologies in terms of efficiency and economics.

The cost of treatment is best portrayed as cost per gallon of dewatered solids since the cost per gallon of biosolids pumped into a geotube is dependent on the solids content of the material being treated. If the sludge being pumped into the tube is 1% solids, the cost of the tube is approximately US\$0.0025 per gallon treated (Don Bishop, per. comm., 8 February 2004). If biosolids are 4% solids, the cost of the tube would be approximately US\$0.01 per gallon treated.

Acknowledgements

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Any opinions, findings, conclusions, or recommendations expressed in this presentation are those of the authors and do not necessarily reflect the view of the US Department of Agriculture.

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Questions

