

Algae dewatering system design from Harvest to Paste

Ashok Damle
Techverse, Inc.

Presentation at
2019 Algae Biomass Summit, Orlando, FL
September 18, 2019

Presentation Overview

- Algae harvesting and dewatering may contribute ~25% or more of the cost of algal products – Need careful selection of an optimal process
- Requirements of algae harvesting system
 - Algae species, cultivation, downstream processing, operation mode, scale
- No single economic solution to “fit all” and provide target concentration range
- Two-step algae dewatering likely for economical harvest to paste operation
 - Pre-concentration step followed by secondary dewatering step to target
- Pre-concentration step to produce 1-5 % w/w concentration from harvest
 - Gravitational settling, Dissolved air flotation, Hollow fiber membrane, others
- Secondary concentration step to produce target 15-25% w/w concentration
 - Centrifugation, Vacuum/pressure filtration, SmartFlow membrane filtration
- Concluding remarks

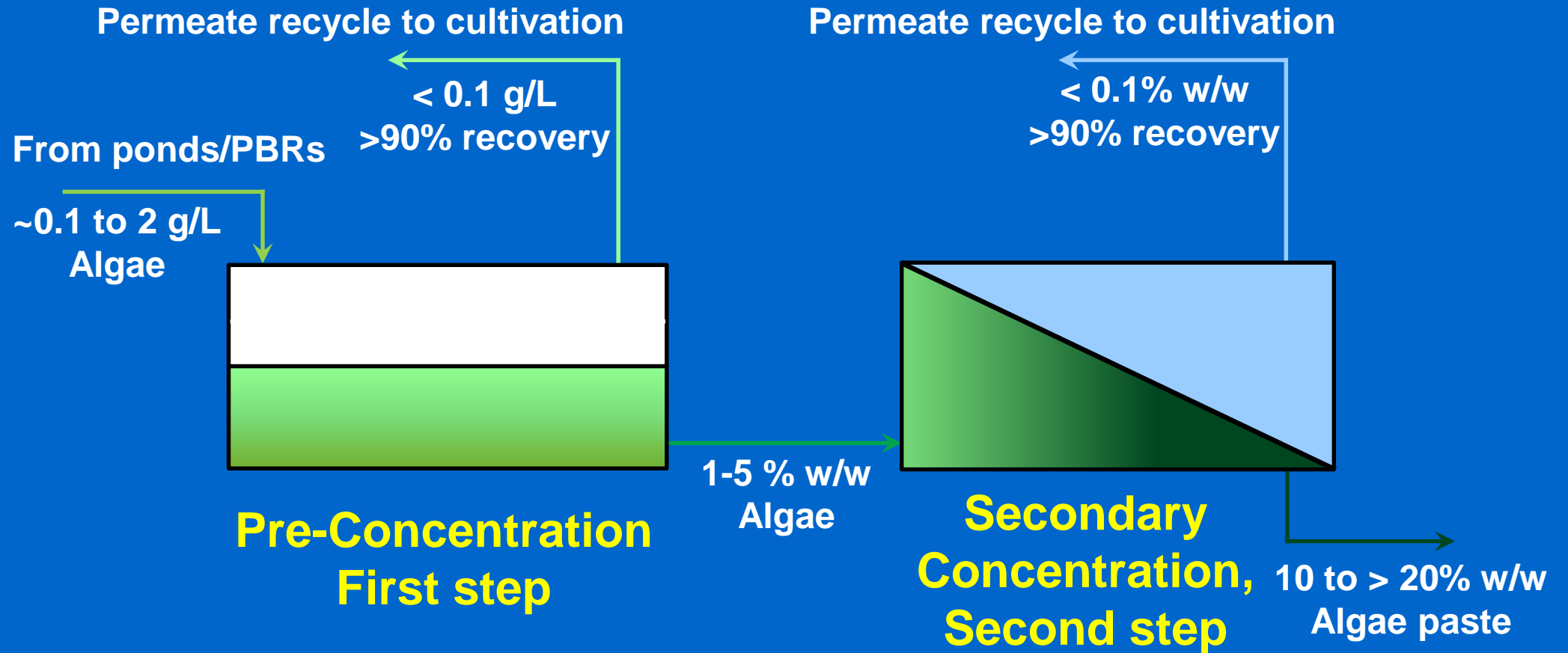
Algae dewatering system considerations

- Algae source
 - Cell species, Size/shape, Fragile nature
 - Growth environment – dissolved salts/nutrients, pH
- Harvested algae concentration
 - Raceway ponds, Photobioreactors (PBRs)
 - 0.1 g/L to 2 g/L depending on several cultivation and growth factors
- Desired target concentration of dewatered algae
 - End use: e.g. animal/fish feed, nutraceutical, biofuel, wastewater tmt
 - Downstream processing after dewatering often determine target
 - 100 g/L to >200 g/L (10% w/w to >20% w/w)
- Scale of operation –
 - Small batches for specialty products vs large scale for commodity ones

Algae dewatering system considerations (cont.)

- Algae solids concentration factor needed in dewatering
 - 100x to 1000x depending on feed/target concentrations
 - Need to remove ~99% to ~99.9% of water
- Modes of operation
 - Depend on algal product produced and scale of operation
 - Dewater a batch of Algae harvest in a specified time
 - Long term continuous operation: Algae Harvest feed rate
- **Two-step process likely needed for economical dewatering**
 - Pre-concentration for algae concentration up to 10-50 g/L
 - Second step to achieve target algae concentration to 100 to 200 g/L
 - Can be semi-batch depending upon dewatering systems

Two-Step Algae Dewatering Process



Pre-concentration Technologies

- **Gravitational settling**

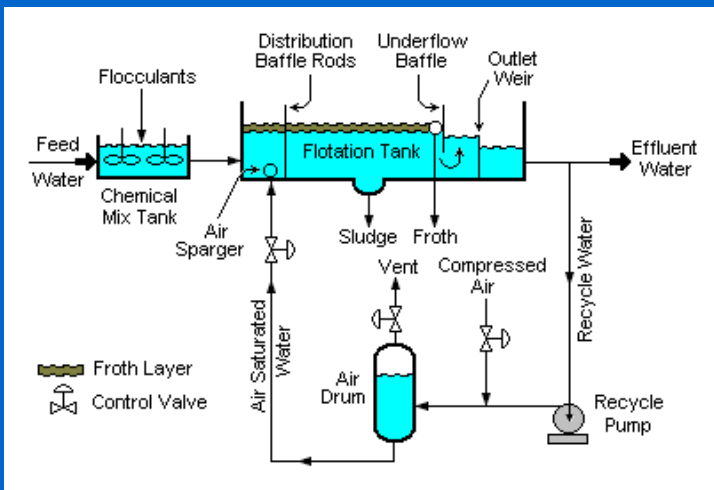
- Need to have sufficient settling rate for feasibility
- Not amenable for all algae species
- Flocculating agents can enhance settling – chemical or biological
- With chemical coagulants, up to 30 g/L concentration possible
- With bio-flocculation, up to 10 g/L concentration possible
- If feasible, likely to be integrated with algae cultivation, e.g. additional settling pond or tank with sufficient settling time
- If feasible, likely to be the lowest cost pre-concentration option
- Flocculant contamination - issue for downstream processing and algal products quality



Pre-concentration Technologies (cont.)

- **Dissolved air flotation (DAF)**
 - Needs chemical flocculating agents for high algae recovery
 - Algae species' ability to adhere onto gas bubbles is key
 - Surfactants assist in algae attachment to bubbles
 - With chemical coagulants, up to 50 g/L concentration possible

- Energy consumption is significant - air compressor
- Established technology for wastewater treatment
- pH, flocculant, surface charge, air rate determine recovery
- Flocculant contamination - issue for downstream processing and algal products quality



Pre-concentration Technologies (cont.)



- **Hollow fiber membrane module technology**
 - Flow direction – outside in or inside out
 - Flow configuration – Cross flow or dead-end filtration
 - Applicable to all algae species
 - 100% algae recovery possible with UF membrane
 - Needs regular backflushing with air or permeate for steady operation
 - Needs membrane cleaning at regular intervals
 - Established technology for water treatment
 - Large (~40-60 m²) low-cost UF membrane modules available
 - Up to 10-15 g/L concentration typical although 50 g/L possible
 - Modular and Scalable technology
 - Energy consumption is significant for pumping and air compressor

Pre-concentration Technologies (cont.)

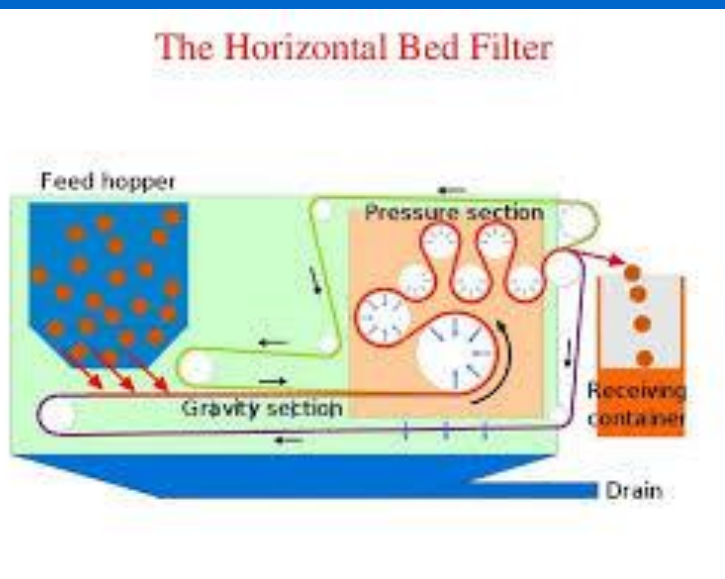
- **Other possibilities**
 - Electro-coagulation
 - Algae cells need to coalesce in electric field
 - May also need coagulants to enhance recovery
 - Up to 5% w/w concentration may be possible
 - Acoustic coagulation
 - Algae cells need to coalesce in an acoustic field
 - Low concentration factor and low algae recovery
 - Magnetic particles
 - Algae cells attach to magnetic particles separated in a magnetic field
 - Needs separation of magnetic particles for algae recovery

Second step - concentration Technologies

- **Centrifugation**
 - Algae suspension is spun at high speeds for separation
 - Several batch designs/formats commercially available
 - Basket, Decanter, Parallel plate
 - Energy consumption is high
 - Smaller algae species need greater energy for separation
 - Up to 300 g/L concentration possible
 - Algae recovery is high although not 100%
 - Cell lysis is a concern for fragile algae species
 - Established technology in food/pharmaceutical industries
 - Fixed capacity units, not scalable

Second step - concentration Technologies (cont.)

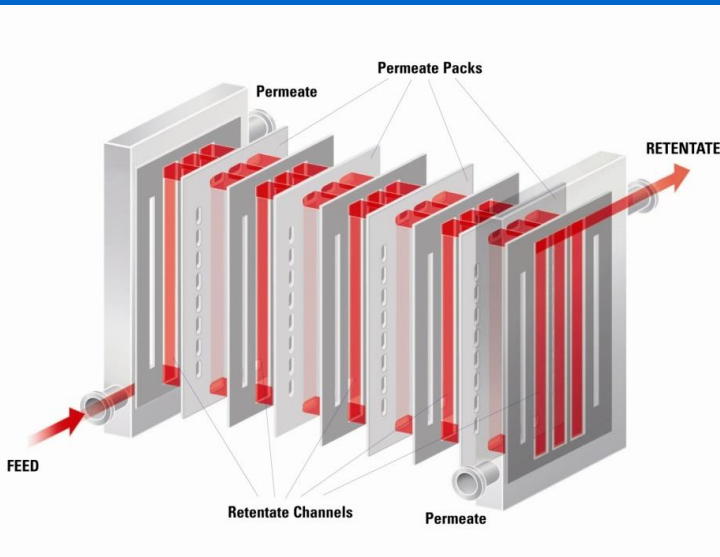
- **Vacuum or pressure filtration – e.g. belt filter, filter press**
 - Rely on filter cake formation on porous cloth filter for high recovery
 - Suitable for large size agglomerated algae species
 - Low recovery with smaller size algae species



- Up to 250 g/L concentration possible
- Needs frequent belt washing for continued filtration
- Filter clogging leads to frequent filter replacement
- Low capacity units, scale-up issues

Second step - concentration Technologies (cont.)

- **SmartFlow Technologies membrane module technology**
 - Continuous cross-flow filtration (tangential flow filtration, TFF)
 - “Open channel” technology for free flow of solids on feed side eliminating limitations of other membrane formats e.g. hollow fiber
 - Increasing channel height with increasing solids concentration
 - Up to 300 g/L concentration possible
 - 100% algae recovery possible with UF membrane
 - Modular and scalable technology
 - Energy consumption is low at large scale
 - New process demonstrated in a pilot scale system for several commercial algae strains to produce algae paste



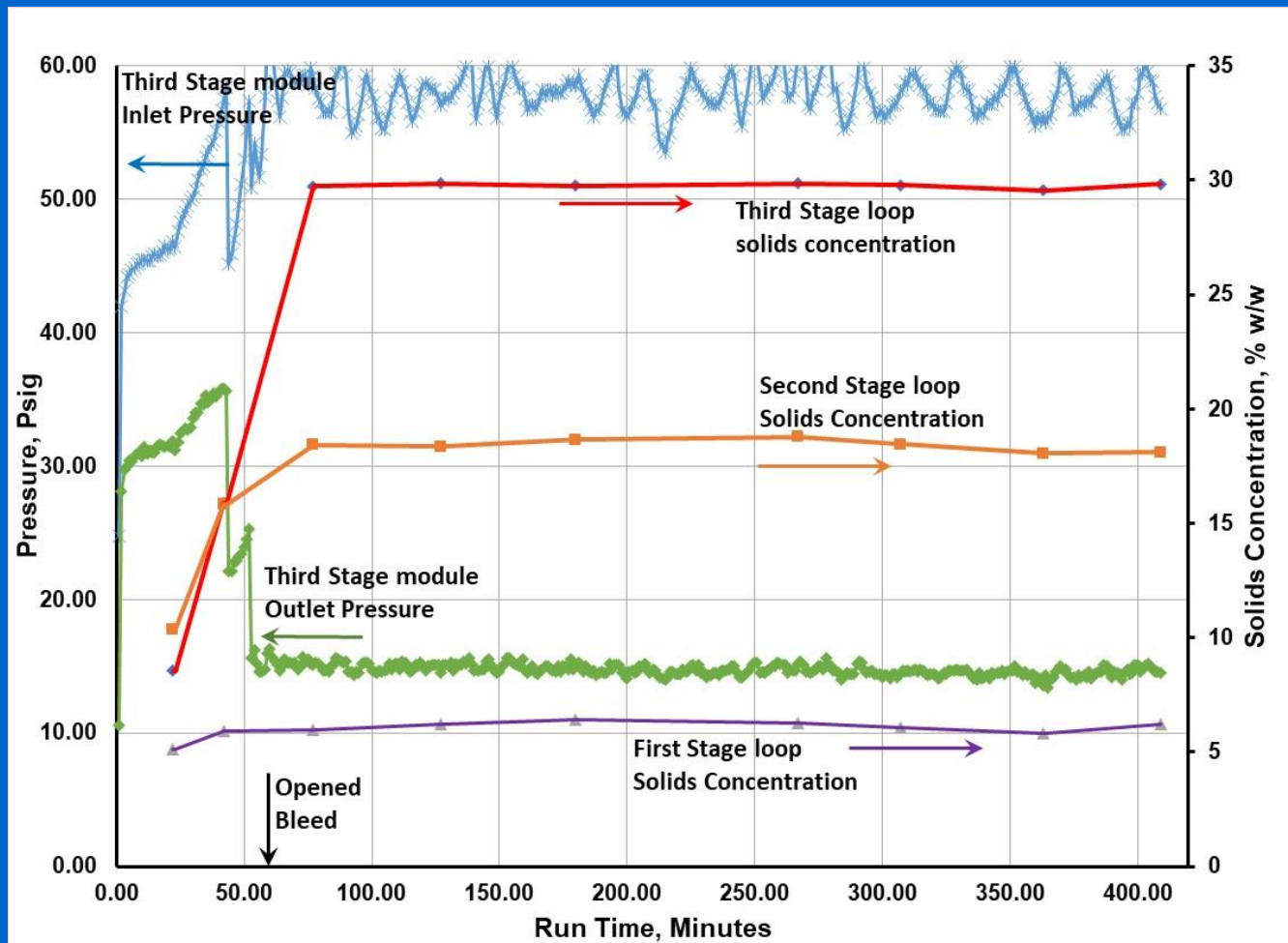
Advantages of SmartFlow Membrane Modules

- Uniform flow velocity over all of the membrane surfaces
 - Utilizes 100% of membrane surface area
 - Provides equal filtration performance in all membrane areas
- Equal fluid path length in all flow channels - Equal flow resistance for each fluid element passing through the module
 - Avoids channeling and dead spots
- Increasing channel height with increasing solids concentration
 - Easily handles fluids with high solids content, high viscosity
 - Allows producing high solids content algae concentrates
- Three interacting controllable factors determine TFF efficiency and permeate flux rate - Channel Height, Shear (velocity), and Feed Pressure

Two-Step Algae Dewatering Pilot Scale Tests with SmartFlow membrane module technology (U.S. DOE SBIR)

- Algae Pre-concentration by hollow fiber membrane modules
- Continuous, Steady state, Step-2 concentration by a 3-stage, 100 L/hr skid
- Eight different algae species provided by AzCATI
- Pre-concentration by hollow fiber modules – 3 g/L to 22 g/L
- Step-2 paste concentration – up to 30% w/w depending on algae species, growth conditions, and operation - feed rate, feed concentration, pressure
- Permeate – clear, algae-free in all runs
- Cleaning protocol restored membrane performance
- Long-term (24 hour), run-on-run reproducible, dewatering performance demonstrated in spite of algae grown in dirty wastewater with coagulants

Typical pilot-scale algae dewatering performance



Initial dead end operation to build solids concentration in each stage

Open paste bleed after reaching target Paste concentration

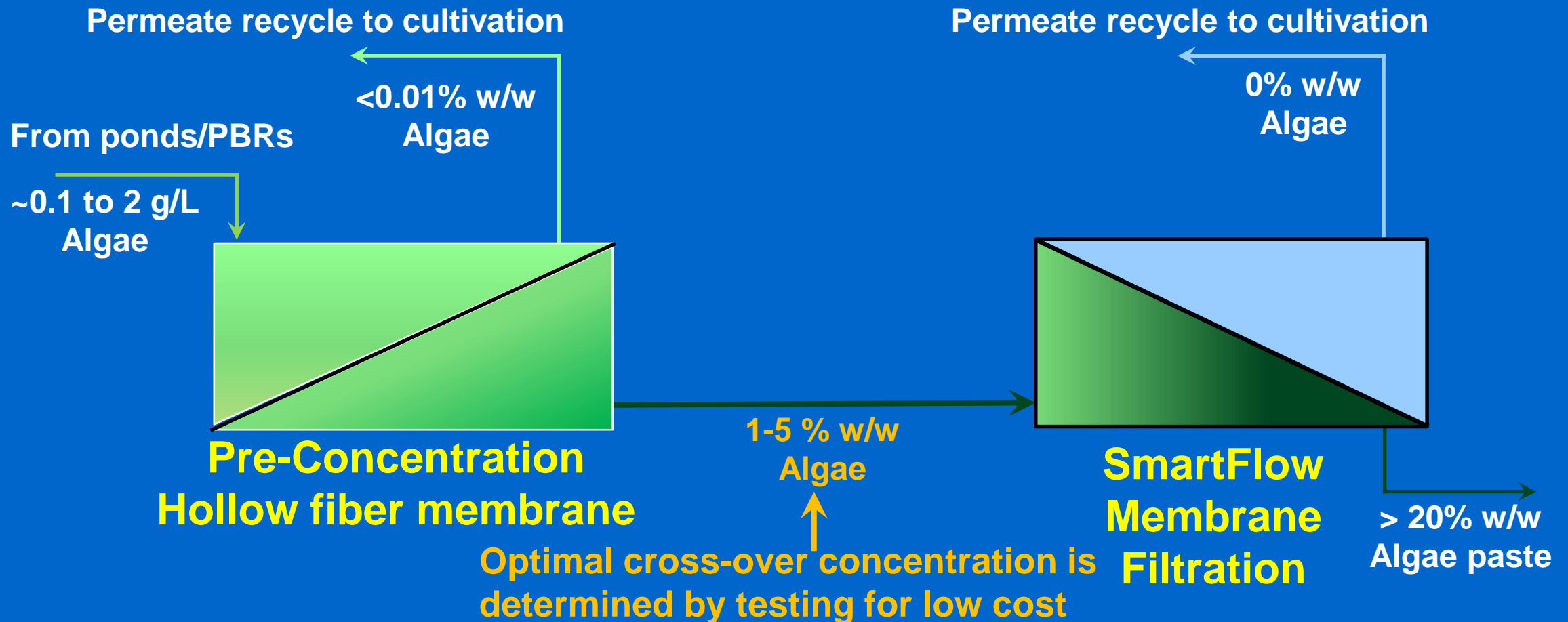
Plot shows one test with:
Feed rate - 100 L/hr

Feed conc. – 2.2% w/w

Steady state output

Paste conc. – 30% w/w

Techverse 2-Step Algae Dewatering Process



Videos of Algae Paste Collection – Please visit Booth # 202



Nannochloropsis - <https://youtu.be/Niu-wRooOgM> , <https://youtu.be/zJMYi4ipkbQ>

Kirchneriella - <https://youtu.be/ARH-PxXVH6c> , <https://youtu.be/F0WLyNRPQnQ>

Marine algae - <https://youtu.be/DKz1HzP6zgc> , Pediatrum - <https://youtu.be/e9gFPsvdabA>

Mixed Scenedsmus, Chlorella - <https://youtu.be/RySdfMG5YmE>

Proprietary - https://youtu.be/c7rBYl_9Yso , <https://youtu.be/HnKJ7u8Jld4>

More information? Questions? Consultation?

Contact:

Dr. Ashok Damle
Techverse, Inc.
919-454-8461

techverse@hotmail.com

adamle@techverseinc.com

http://techverseinc.com/algae_dewatering/