NORDIC AQUAFARMS
SUSTAINABLE AQUACULTURE

WASTEWATER TREATMENT

NORDIC AQUAFARMS RAS PROJECT

MAINE, USA Sept 11th 2018

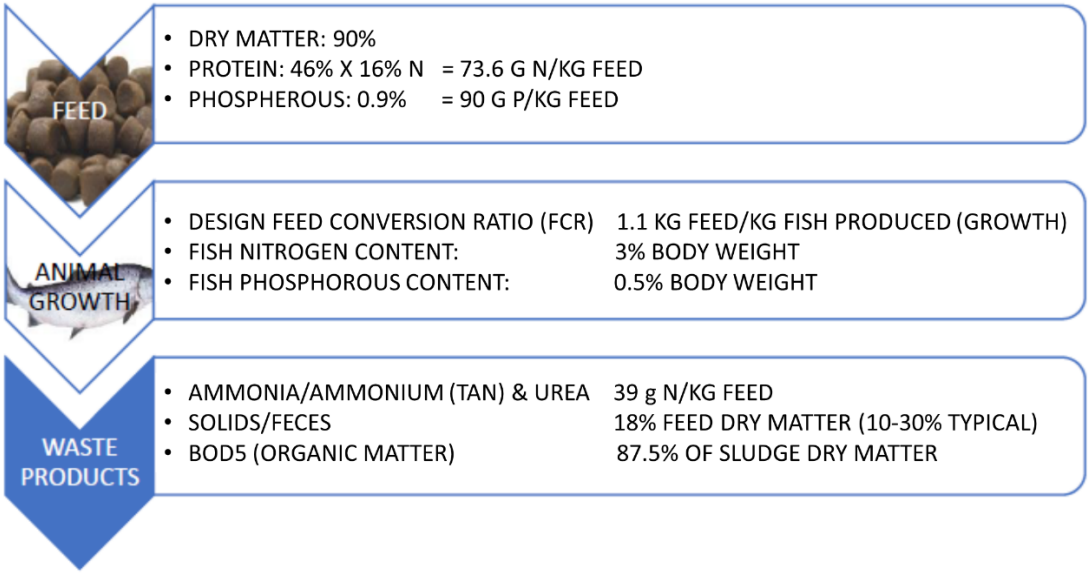
In relation to the planned aquaculture project by Nordic Aquafarms Inc. in Maine, USA, we hereby provide an overview of the Effluent/Wastewater treatment plant technology.

INTRODUCTION & BACKGROUND

The project concerns a land-based production of Atlantic salmon from eggs to market size, using proven state-of-the-art Recirculation Aquaculture System (RAS) technologies for maintaining optimal water quality for fish production with minimal water exchange.

PRODUCTION & POLLUTANTS

As with any animal production, nutrients are generated from the feed and animal metabolism. The exact composition varies with nutritional requirements for species and size as well as manufacturer, but essentially consists of proteins, lipids, carbohydrates, phosphorous and minerals. Of importance when considering environmental impact, is the BOD, total N and P.



TOTAL PARAMETERS FOR NORDIC AQUAFARMS, MAINE:

Wastewater treatment is undertaken in two steps:

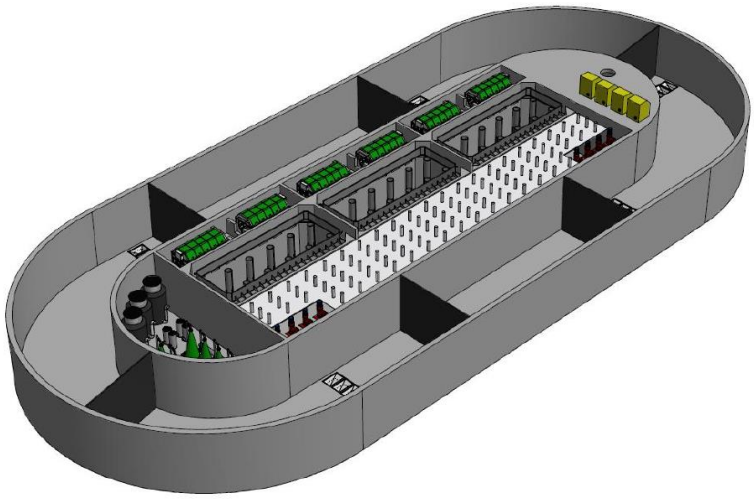
1. **Primary internal water treatment system (Recirculating Aquaculture System)**

   Function: Mechanical, biological and gas balancing in order to maintain a high level of water quality suitable for culturing Atlantic Salmon

2. **Effluent/Wastewater Treatment Plant**

   Function: Mechanical, biological and chemical treatment of final discharge

1. RAS DESCRIPTION



Water Flow in a D-ended RAS

The total tank volume in a production unit is 8500 m^3. Water circulation is 2 x tank volumes per hour or 17,000 m^3 / hour. The water flows from the tank by gravity through several outlets at the bottom of the tank effectively removing feces/feed residues from the tank to the water treatment units, where it is mechanically treated by drum filters with 60 µm mesh size. In order to backwash the drum-filters, spray water is taken from the Denitrification MBBR (ref. below) where total N concentrations are lowest.

From the drum filters the water is led by gravity to the aerobic Moving Bed Bio-Reactors (MBBRs) for biological treatment of ammonium to nitrate and reduction of organic matter.

A side-stream of approx. 8% of the recirculating flow is diverted on a loop after aerobic biological treatment through a second MBBR, operating under anoxic conditions for denitrification of nitrate to free nitrogen.

After mechanical / biological cleaning, the water passes over the central CO2 degassing unit mounted above the pump. The CO2 degassing unit consists of a countercurrent flow cascade based on a water distribution with "Crown Nozzles" and dimensioned at an air / water rate of 8:1. The suction effect by the ventilation in the cascade forms a small vacuum, which also removes any N2 gas supersaturation. Alkalinity / pH control is done automatically via the SCADA system which uses duplicate sensors to measure pH in the pump sump. If the values produced by the two sensors do not match, an alarm is triggered, and the dose is stopped. This ensures optimal levels of pH and alkalinity for the fish and nitrifying bacteria in the bioreactors.

The water is from the pump sump pumped back to the tank with Lykkegaard propeller pumps. Oxygen is added partly into the main water supply line and partly with high pressure oxygen cones.

WATER QUALITY PARAMETERS IN CULTURE TANK AT MAXIMUM FEEDING

PARAMETER	VALUE	UNITS
Oxygen	≥ 95%	Saturation
Total Ammonium (TAN)	≤ 1.5	mg NH4-N/l
Nitrite	≤ 0.5 /	mg NO2-N/l
Nitrate	≤ 100	mg NO3-N/l
CO2 (free)	≤ 15	mg CO2/l
Turbidity	≥ 5 - ≤ 0.7	NTU
Suspended matter	≤ 10	mg/l

Waste Water Treatment Process Overview

All water discharge pipework from the RAS come directly from the internal water treatment system's mechanical filters and (to a lesser extent) system overflow pipes.

The pipes will all lead to the central Waste Water Treatment Plant (WWTP).

The WWTP is designed for peak flow capacity of the rinse/backwash water from internal mechanical filtration in the RAS as indicated on the attached P&ID.

All water used for backwashing the rotating drum filters is taken directly from the internal RAS denitrification bio-reactor where the Total Nitrogen (TN) level is lowest. The denitrification unit is designed to maintain NO3-N levels between 10-30 mg NO3-N/l.

Design specifications Waste Water Treatment Plant (WWTP)

WWTP SEQUENCE OF TREATMENT:

1. Aerobic Moving bed bio-reactor (MBBR)
2. Chemical precipitation of total P
3. Micro-Filtration (0.4 µm pore size) in Membrane Bio-Reactors (MBR)
4. Sludge Dewatering, decanter centrifuges, supernatant returned to biological treatment
5. Final liquid effluent UV-C sterilization prior to discharge

BIOLOGICAL PRE-TREATMENT

All wastewater from the RAS units is lead directly to an equalization tank/pump station and into the primary biological treatment for additional total nitrogen (TN) removal.

The biological treatment is based on proven Moving Bed Bio-Reactor (MBBR) technology. The designs are based on practical experience from the engineering team over many years and consistent with common design practices (Metcalf & Eddy and ASCE 5th Edition "Design of Municipal Wastewater Treatment Plants").

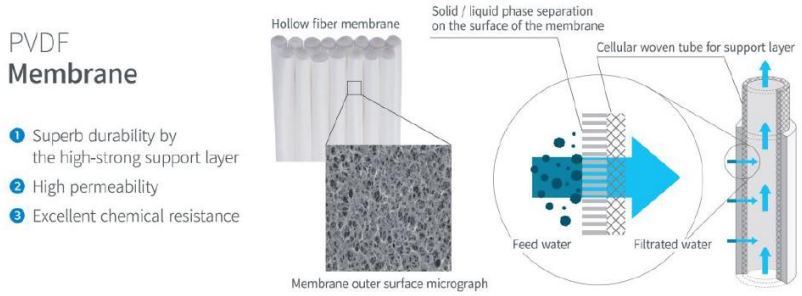
1. 4 x Aerobic MBBR in parallel: Soluble BOD oxidation
   Volume/aerobic MBBR: 150 m^3/tank
   Total Volume: 600 m^3
   HRT: 30 min (peak)
   Peak Loading: 20,160 kg BOD/day
   Carrier Fill Fraction: 50%
   Carrier Elements: bulk surface area: 800 m^2/m^3
   Total Carrier Surface: 240.000 m^2
   Total BOD carrier loading rate: 84 g COD/m^2/day
   Soluble BOD removal rate: 30 g BOD/m^2/day
   Aeration Requirement: 3000 Nm^3/hr, coarse bubble

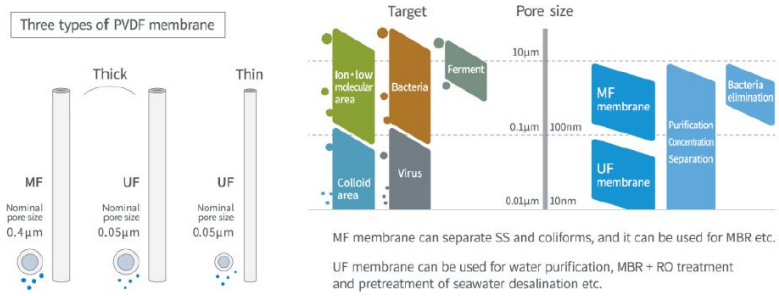
The biological treatment is installed with capacity for variable recirculation flow from the aerobic to the pre-anoxic MBBR for N removal.

Biological phosphorous removal will occur in practice via aerobic/anoxic MBBRs used. and will be designed for removal only by chemical precipitation/MBR removal below.

BIOLOGICAL/MECHANICAL POLISHING TREATMENT

For final polishing, water from the biological treatment is passed through STERAPORE Hollow Fiber Membrane Bio-Reactors from world-renowned Mitsubishi with in-line addition of FeCl for phosphorus precipitation.





Here, fine solids removal takes place with 0.4 µm mesh membranes (Micro Filtration) These effectively remove and allow for additional aerobic biological polishing. Outlet TSS is maintained at a constant level of 1.5% (Ref. Mitsubishi design requirement) and measured with in-line real-time TSS measurement.

The MBR units are equipped with automatic Clean-In-Place (CIP) systems.

Membrane Modules: 56M2400FF

Design Flow: 1218 m^3/hr (peak)

Membrane surface/module: 2400 m^2

Membrane Tank Volumes: 4 x 200 m^3 (800 m^3 total) in parallel

Total number of modules: 24

Total membrane Surface: 24 x 2400 m^2 = 57.600 m^2

Membrane surface area: 2400 m^2 per module x 4 modules x 4 treatment trains = 28.800 m^2 total

Design Flux: 0.3 m/day avg. 0.5 m/d peak

Design MLSS concentration: 10.000 mg/l

The permeate is drawn by lobe pumps through UV-C sterilization to discharge and the retentate is pumped to the sludge thickening unit.

SLUDGE THICKENING

Captured sludge from the MBR treatment is pumped to the sludge thickening unit for reduction of sludge volume.

Sludge thickening consists of decanter centrifuges, provided by Alfa Laval.

Separation takes place in a horizontal, cylindrical bowl equipped with a screw conveyor. The sludge enters the bowl through a stationary inlet tube and is accelerated smoothly by an inlet distributor. The centrifugal force that results from the rotation then causes sedimentation of the solids on the wall of the bowl.

The conveyor rotates in the same direction as the bowl, but slightly slower, moving the solids towards the conical end of the bowl. The cake leaves the bowl through the solids discharge openings into the casing. Separation takes place throughout the entire length of the cylindrical part of the bowl, and the clarified liquid leaves the bowl by flowing over adjustable plate dams into the casing.

Decanter Centrifuge: 3 x Aldec 45 Decanter Centrifuge

Design Flow: 40 m^3/hr, 1.5% DS in feed/unit

Thickened Sludge: 10 – 20% DS in outlet cake

Liquid fraction: Return to MBBR

Comments on the technology and design criteria:

The processes in the design of the WWTP and associated technologies/equipment have all been proven in domestic and industrial wastewater treatment industries as well as in RAS facilities. The chosen suppliers of the MBR and sludge thickening are both well-known and respected internationally for quality and performance.

The level of treatment prior to discharge is, however, unprecedented in aquaculture to our knowledge. Common requirements for RAS projects are typically limited to BOD/TSS removal > 70%. Due to increased legislation and increase in the industry in general, more measures are now being installed to reduce nitrogen loads and, to some extent, phosphorous.

The performances of the Membrane Filters with precipitation of total P as well as the dewatering have been confirmed by the suppliers (Mitsubishi and Alfa Laval, respectively) and biological treatment performance is deemed well within safety in design criteria.

The WWTP operations and removal efficiencies exceed standard practices for municipal and industrial wastewater.

With kind regards,

Simon Declan Dunn

Senior Engineer, Nordic Aquafarms

Slough from Drum filter
D tanks

Buffer tank

pump

Inline mixer

Intake Water

Fe

Acid CIP unit one time pr week

CIP sodium hypochlorite NaClO

Lobe pump

UV

Buffer tank

Efulent

Drain

Bioreaktor85
50m³

Bioreaktor
50m³

Air pump

Air pump

MBR Filter
60m³

MBR Filter
60m³

Air pump

Inline drymatter

Air pump

Slough out

Inline drymatter

Buffer tank

Slough out

pump

pump

Decanter

Return loop from bioreaktor

Return to MBR filter

pump

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NAF Denmark

	Date	Name
Drawn	25-09-18	SK
Checked	25-09-18	SD
Approved	xx	xx

Drawing title: Waste water plant

Drawing number: xx

Revison: 06

Sheet: 1

Project: NAF WWTP US

xx

Construction Schedule

This schedule will commence upon final receipt of all necessary permits and approvals for the project.

1. Construction start within 1-3 months of completion of permitting. To include infrastructure connection to site, landscaping, smolt facility and waste water treatment plant.
2. Construction start of grow-out modules and processing facility approximately 6-9 months after initial construction phase. Final steps in Phase 1 construction is expected to be complete in 12-15 months.
3. Timeline for Phase 2 expansion (additional smolt and grow-out modules), will be decided once Phase 1 development is complete.