Green Aquaculture Intensification

This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement N° 773330

Valorization of aquaculture side streams
(I) Background

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Salten Havbrukspark waister ANFACO CECOPESCA

Welcome to this unit on the valorisation of aquaculture side streams, prepared by Christian Bruckner, Martiña Ferreira Novio, Johan Johansen & Hallstein Baarset. In part 1 we consider the background issues and drivers for better valorization of aquaculture side-streams.

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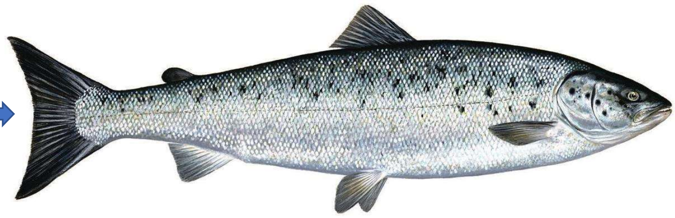
Background: Norwegian salmon farming mass balance

INPUT
Fish: 300.000.000 smolt
Feed: 1.600.000 tonnes feed



OUTPUT
Fish: 1.250.000 tonnes

SIDE-STREAMS:
Mortalities: 60.000.000 fish (some 60.000 tonnes)
Waste feed, faeces & excretion: 275.000 tonnes dry sludge
Other: Pathogens, treatments, etc.

If we control the aquaculture side streams, we control the environmental footprint

Looking at the salmon farming industry in Norway, 1.250.000 tonnes of fish are produced anually, using 1.600.000 tonnes of feed. The side streams of fish production accounts for approximately 60.000 tonnes of dead fish (called mortalities) and 275.000 tonnes waste feed, faeces & excretion (estimated as dry sludge).

Typical fish losses in sea cages accounts for 15 – 20 % of the fish by numbers, equalling 6 – 9 % of the biomass. This represents about 53 million fish and an annual value loss of ≈100 M€ in Norway alone.
Additional losses in land-based aquaculture accounts for 59 million mortalities and 52 million discarded fish.

The current method for mortality disposal faces challenges regarding Health, Safety and Environment (HSE), due to the practice of ensiling dead fish with formic acid. This is because the practice of mortality ensilage in Norwegian aquaculture accounts for 2 fatalities, 62 serious and many minor injuries per decade.

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Background: waste water

Legislation-driven technology development: removal of dissolved or particulate matter is not mandatory in general, but all new farming licenses awarded for land-based aquaculture need to reduce the particulate matter/suspended solids (SS; defined as particles larger than 0.45 µm) by, at least, 50 % and the organic content by, at least, 20 % (measured as chemical or biochemical oxygen demand; COD or BOD; mg O_2 l^{-1}).

Effluent characteristics:

- Dry matter (SS): 0.02% (0.17 kg dry sludge per kg feed)
- Phosphorus: 9 mg/l
- Nitrogen: 7 mg/l (95% ammonium NH_4^+)
- Salinity: 1‰

GAIN test-site in Sundsfjord, Norway
S3 filter dryer:
SS removal 96%
Chemical Oxygen Demand (COD) removal 86%

Salten Havbrukspark

Fish sludge is extremely diluted, with small particles, little fibre and relatively sticky compared to other sludges

The purification of aquaculture wastewater is based on a legislation-driven technology development: the removal of dissolved or particulate matter is not mandatory in general in Norway, but all new farming licenses awarded for land-based aquaculture need to reduce the particulate matter/suspended solids (SS; defined as particles larger than 0.45 µm), by at least 50 %, and the organic content by at least 20 % (measured as chemical or biochemical oxygen demand (COD or BOD; mg O_2 l^{-1}).

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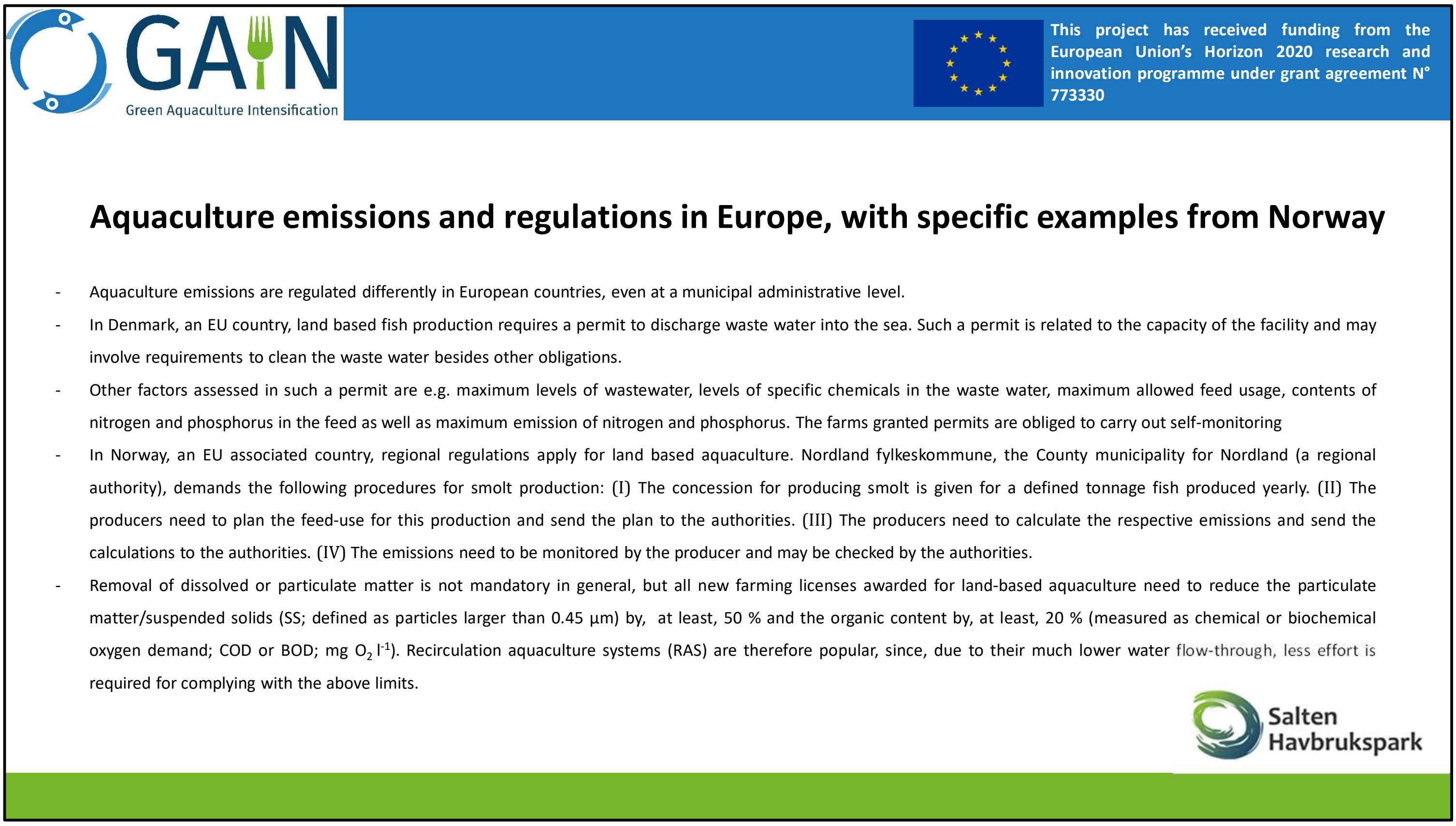
Background: physicochemical waste water characteristics from smolt production

Wastewater	Observed values	Analytical method
Suspended solids (>0.45µm) (n=8)	0.006-0.180 %	EN872
Particle size (n=6):		
- Median diameter	0.097-0.469 mm	ISO13320
- Average diameter	0.170-0.569 mm	ISO13320
Organic matter:		
- biochemical oxygen demand (BOD) (n=4)	100-200 mg l^{-1}	EN1899-1
- chemical oxygen demand (COD) (n=6)	219-2290 mg l^{-1}	ISO15705
Chloride (Cl^-) (n=3)	620 - 1960 mg l^{-1}	SM 17 udg. 4500-NH3
Conductivity (n=3)	47.6-242 mS m^{-1}	ISO7888
Total phosphorous (n=4)	6.2-9.3 mg l^{-1}	ISO6878
Orto-phosphate (n=2)	1.5 mg l^{-1}	ISO15681-2
Total nitrogen (n=3)	4.3-7.8 mg l^{-1}	ISO15682:2001
Ammonium (n=3)	1.1-6.9 mg l^{-1}	ISO11732
Total fat (n=4)	4.8-27.4 mg l^{-1}	CSN757506

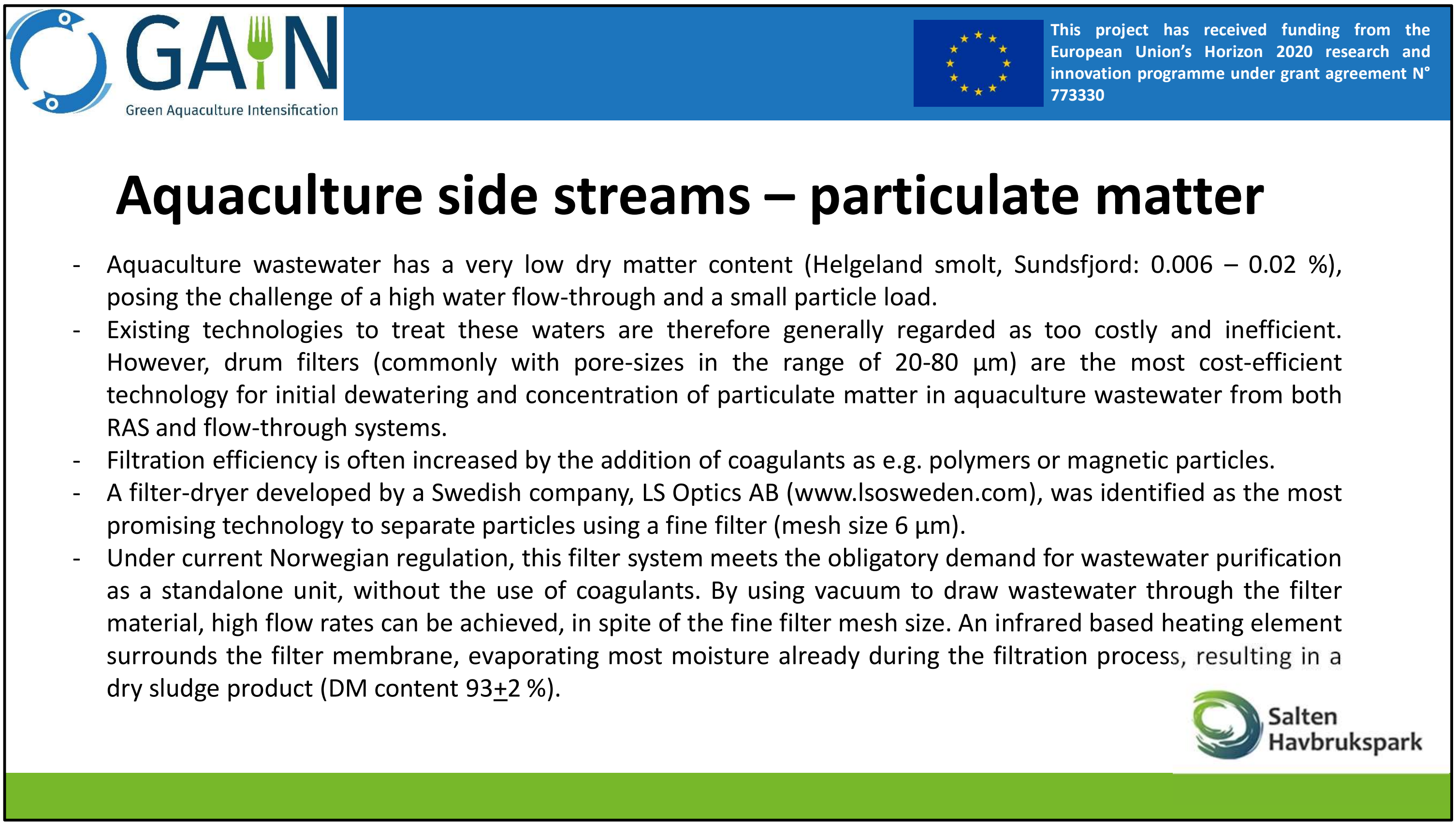
This table lists typical waste water characteristics for land based aquaculture. Please note the low concentrations of nutrients and suspended particles, which pose a major challenge to purify these waters.



Aquaculture emissions are regulated differently between European countries, even at a municipal administrative level. In Denmark, an EU country, land-based fish production requires a permit to discharge waste water into the sea. Such a permit is related to the capacity of the facility and may involve requirements to clean the waste water besides other obligations. Other factors assessed in such a permit include the maximum flow of wastewater, levels of specific chemicals in the waste water, maximum allowed feed usage, contents of nitrogen and phosphorus in the feed as well as maximum emission of nitrogen and phosphorus. The farms granted permits are obliged to carry out self-monitoring

In Norway, an EU associated country, regional regulations apply for land based aquaculture. Nordland fylkeskommune, the County municipality for Nordland (a regional authority), demands the following procedures for smolt production: (I) The concession for producing smolt is given for a defined tonnage fish produced yearly. (II) The producers need to plan the feed-use for this production and send the plan to the authorities. (III) The producers need to calculate the respective emissions and send the calculations to the authorities. (IV) The emissions need to be monitored by the producer and may be checked by the authorities.

Removal of dissolved or particulate matter is not mandatory in general, but all new farming licenses awarded for land-based aquaculture need to reduce the particulate matter/suspended solids (SS; defined as particles larger than 0.45 µm) by at least, 50 %, and the organic content by at least, 20 % (measured as chemical or biochemical oxygen demand; COD or BOD; mg O_2 l^{-1}). Recirculation aquaculture systems (RAS) are therefore popular, since, due to their much lower water flow-through, less effort is required to comply with the above limits.



Aquaculture wastewater has a very low dry matter content (for instance at Helgeland smolt farm in Sundsfjord, this is between 0.006 and 0.02 %), posing the challenge of a high water flow-through and a small particle load. Existing technologies to treat these waters are therefore generally regarded as too costly and inefficient. However, drum filters (commonly with pore-sizes in the range of 20-80 µm) are the most cost-efficient technology for initial dewatering and concentration of particulate matter in aquaculture wastewater from both RAS and flow-through systems.

Filtration efficiency is often increased by the addition of coagulants such as polymers or magnetic particles. A filter-dryer developed by a Swedish company, LS Optics AB, was identified as the most promising technology to separate particles using a fine filter (mesh size 6 µm).

Under current Norwegian regulation, this filter system meets the obligatory demand for wastewater purification as a standalone unit, without the use of coagulants. By using a vacuum to draw wastewater through the filter material, high flow rates can be achieved in spite of the fine filter mesh size. An infrared based heating element surrounds the filter membrane, evaporating most moisture already during the filtration process, resulting in a dry sludge product (DM content 93±2 %).