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# NOTVASK project meeting

## 28.6.2019

# Agenda

- Biofouling control in Norwegian aquaculture (WP1)
- Novel net cleaning technology – test results (WP2)
- Development of future net cleaners (WP3)
  - Recommendations for industrial up-scaling
  - Cost-Benefit analysis
  - Feasibility of automation
- The future of biofouling control in aquaculture (WP4)
- Input project partners: "What are current challenges related to biofouling?
  How should biofouling be controlled in the coming years?"
- Final discussion

# Aim of the NOTVASK project

To develop knowledge, technology and operational methods for cleaning of biofouled net pens.

→ **Improvement of net cleaning with regard to**

- Efficacy & frequency
- Energy and time efficiency
- Reduction of net and coating abrasion
- Reduction of emissions that affect fish health and the environment
- Compliance with the Aquaculture Stewardship Council (ASC) Salmon Standard



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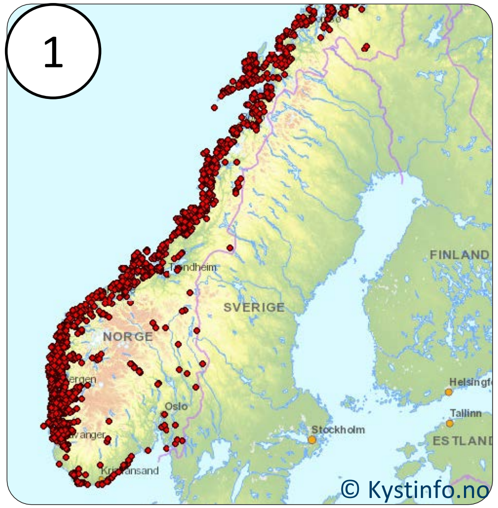
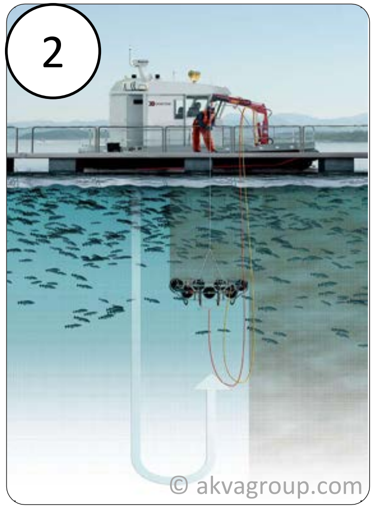
# Overview

1




**Survey** of existing technologies and methods

2




Comparison of high-pressure cleaning to technology based on

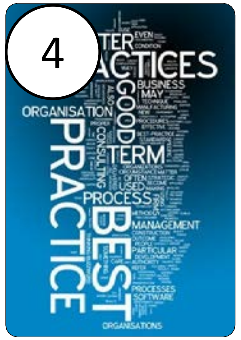
- Low-pressure
- Cavitation
- Suction
- Induction heating

**Testing** of 4 alternative net cleaning methods

3


Cost/benefit analysis and concept studies for **industrial up-scaling**

4




**Best practice guide**

that guides the selection of the most suitable biofouling management concept = combination of net material, coating, cleaning equipment and cleaning frequency



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# WP 1: Biofouling in Norwegian aquaculture

# WP1: Survey of existing technologies and methods

**Aim**: Detailed mapping of existing technology and methods,
and identifying challenges and needs for improvement.

→ Survey of farm personnel & regional managers

74 Marine Harvest sites were contacted between Sept 2015 and June 2016.

Participants from 51 sites delivered answers (= 69 % participation)

**43 questions on**

- Background data → site and the management etc.
- Sea lice situation and management
- Biofouling situation and management
- Fish gill health status



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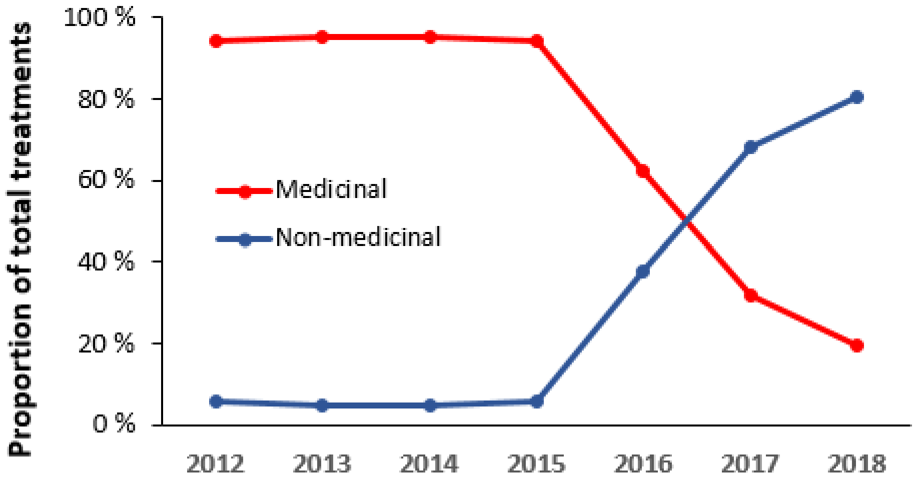
# Sea lice

# Cleaner fish

**Treatment type:**

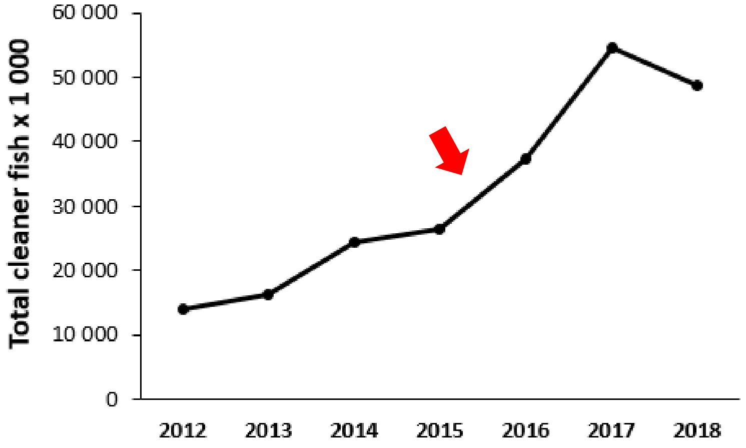
(sites have used this method)

- 90 % medicinal bath
- 45 % medicinal feed
- 20 % non-medical delousing

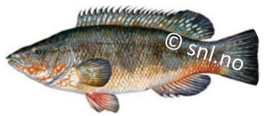



Hjeltnes et al. 2019

**88 % use cleaner fish** (South: 100 %, North: 40 %)








Fiskeridirektoratet 2019

The **main challenges** with cleaner fish are:

- **Survival (69 %)**
- Prevent that they feed on biofouling (29 %)
- Correct feeding (17 %)

# Net coating

**Copper coatings are used…:**

- On all nets (58 %)
- On some nets (8 %)
- Not in use (34 %)

**Increase of ASC certified sites**

2015: 5 % (47 sites)
2018: 14 % (142 sites)

**Exchange of nets:**

86 % change nets *once* during the production cycle

→ On average after 10 months

← Net exchange is more common again!

# Net cleaning

**Main reason for net cleaning:**

cleaner fish performance

**First cleaning to take place:**

With copper: 16 weeks

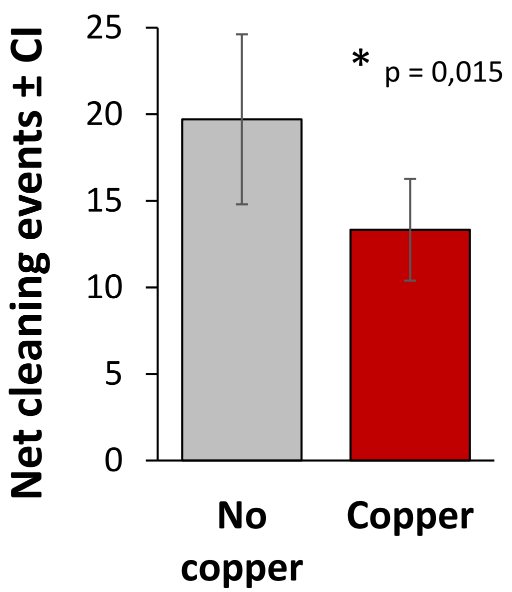
Without copper: 11 weeks

(Range: 2 weeks to 1 year)

**Average cleaning timer (per cage): 5 hrs**

→ 1-2 hrs

**Average cleaning events per grow-out phase**




Maximum: 35x

Minimum: 1x

Average reduction by 6 cleaning events

**!** Only 3 sites **collect information on** the **coating performance** during the production cycle

→ Time it takes before the first cleaning

→ Cleaning interval



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# Effects of cleaning on fish welfare

**Reaction to cleaning:**

81 % report a reaction in the **cleaned cage**

43 % report a reaction in the **neighbour cage**

**73 % report to alter the feeding regime**

→ 44 % stop feeding

→ 29 % reduce feeding

→ **Reactions include**

- Reduced appetite (45 %)
- Jumping (37 %)
- Stress (32 %)
- Gill irritation (5 %)
- Avoidance behaviour (5 %)

➢ **Hydroids can cause gill damage** (Bloecher et al. 2018)

➢ **Net cleaning can lead to elevated stress levels in fish** (Stene 2019)



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Bloecher et al. 2018. PLOS ONE. 13:e0199842; Stene 2019 FriskFisk konferansen

# WP 2: Testing of alternative net cleaning methods

# WP 2: Testing of 4 cleaning technologies

**Chosen technologies:**

1. Induction-based cleaning
2. Low-pressure cleaning
3. Cavitation cleaning
4. Suction cleaning
5. High-pressure cleaning

**Chosen net and coating types:**

1. Uncoated nylon
2. Nylon + Notorius A (regular copper)
3. Nylon + Notorius 3 (copper + omadine)

↳ BF should be easier to clean off

**Experiments:**

1. Cleaning efficacy
2. Effects on cleaning waste
3. Effects on net strength
4. Effects on coating integrity
5. Energy + time consumption
6. Compatibility with ASC standard
7. Cleaning frequency / regrowth ✗
8. Collection efficacy ✗



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# WP 2: Induction-based cleaning

# Induction heating is successful against blue mussels

Metal net with
blue mussel fouling

Best effect after
**3 s exposure**

→ Mussels were "cooked" and fell off the metal or could be scraped off easily

→ It seems the heat destroys the byssus thread
(Mussels may fall off later, if not immediately.)



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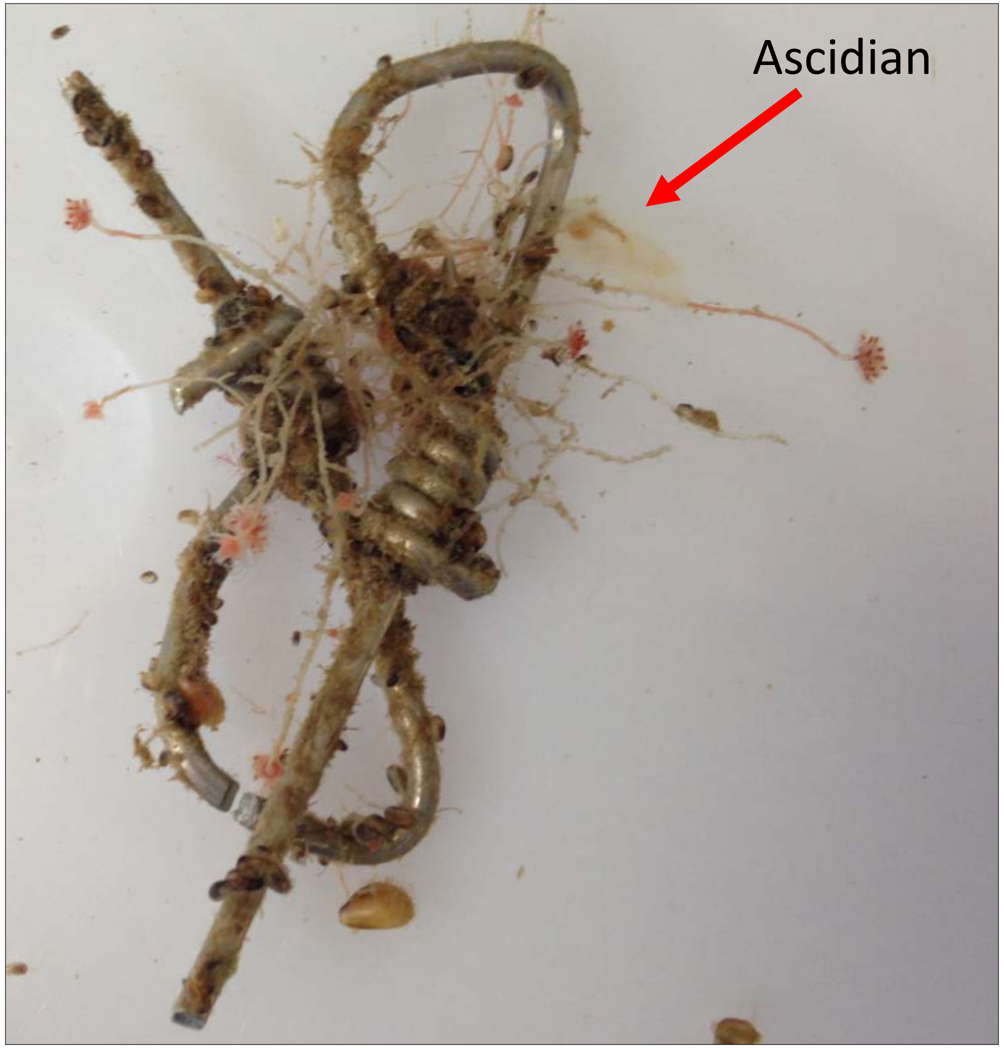
# Treatment of other foulers was not successful

Hydroids



# WP 2: Induction-based cleaning

**Conditions for induction heat to be successful:**

- Close contact/short distance between magnet and net
- High iron content in the net
- Young (=small) biofouling that sits close to the heat source (= net)

→ Extensive testing with water proof unit in sea water needed



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## WP 2: Testing of

- High pressure
- Low pressure
- Cavitation
- Suction

## Effects on

- Cleaning efficacy
- Cleaning waste
- Net strength
- Coating integrity

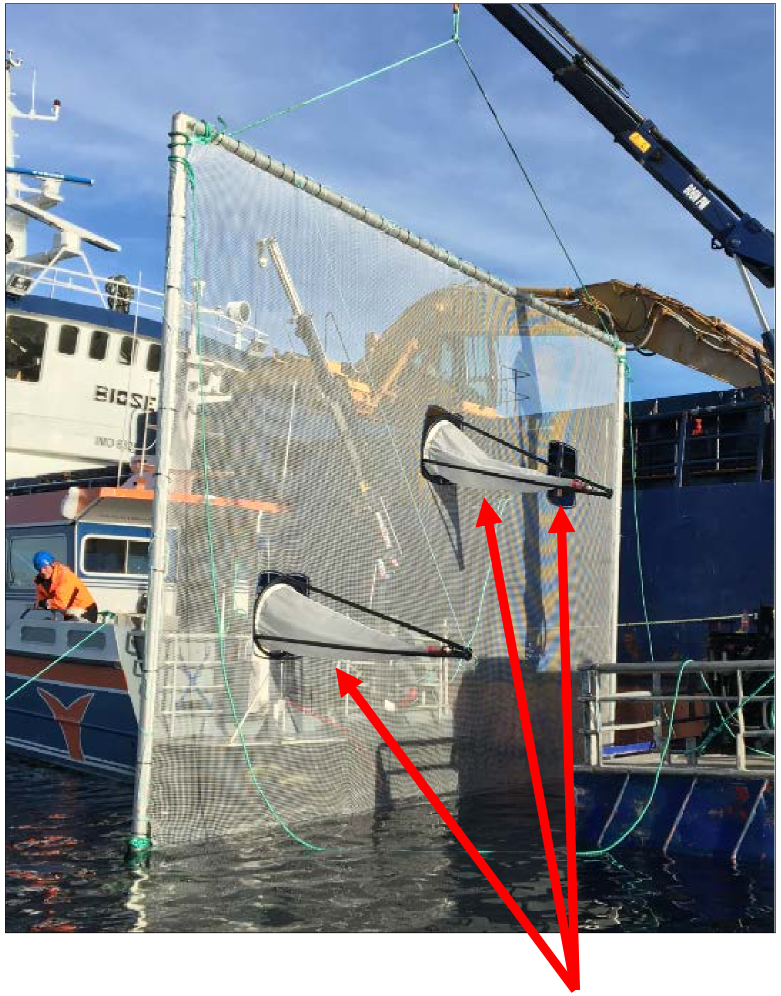
# Experimental set-up

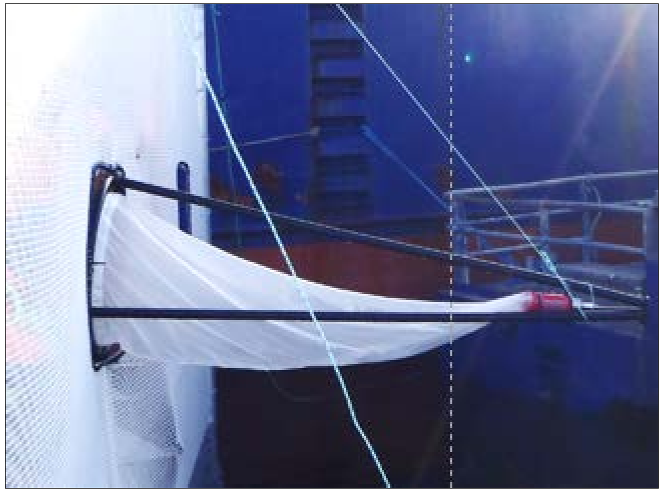
**High pressure: 220 bar (220 L/min)**

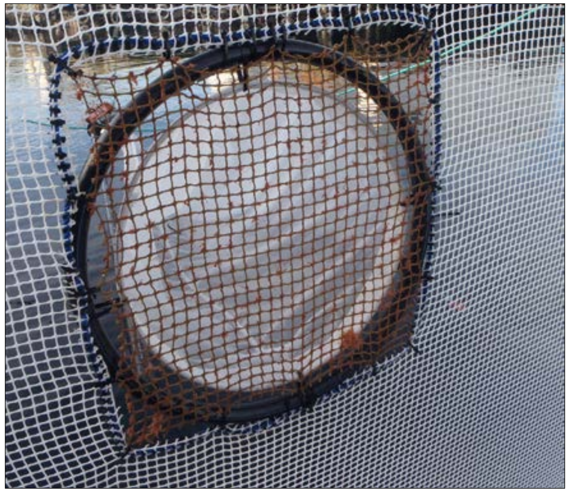
**Low pressure: 80 bar (140 L/min)**

Aluminium frame

# Washing of fouled samples + collection of cleaning waste







Cleaning waste was separated into 3 groups:

- Hydroid colonies → small or large (*20 mm), few or many (*10 polyps)
- Particles ≥ 2.4 mm
- Particles < 2.4 mm

3 net samples, 2 with biofouling collector (150 µm plankon net)



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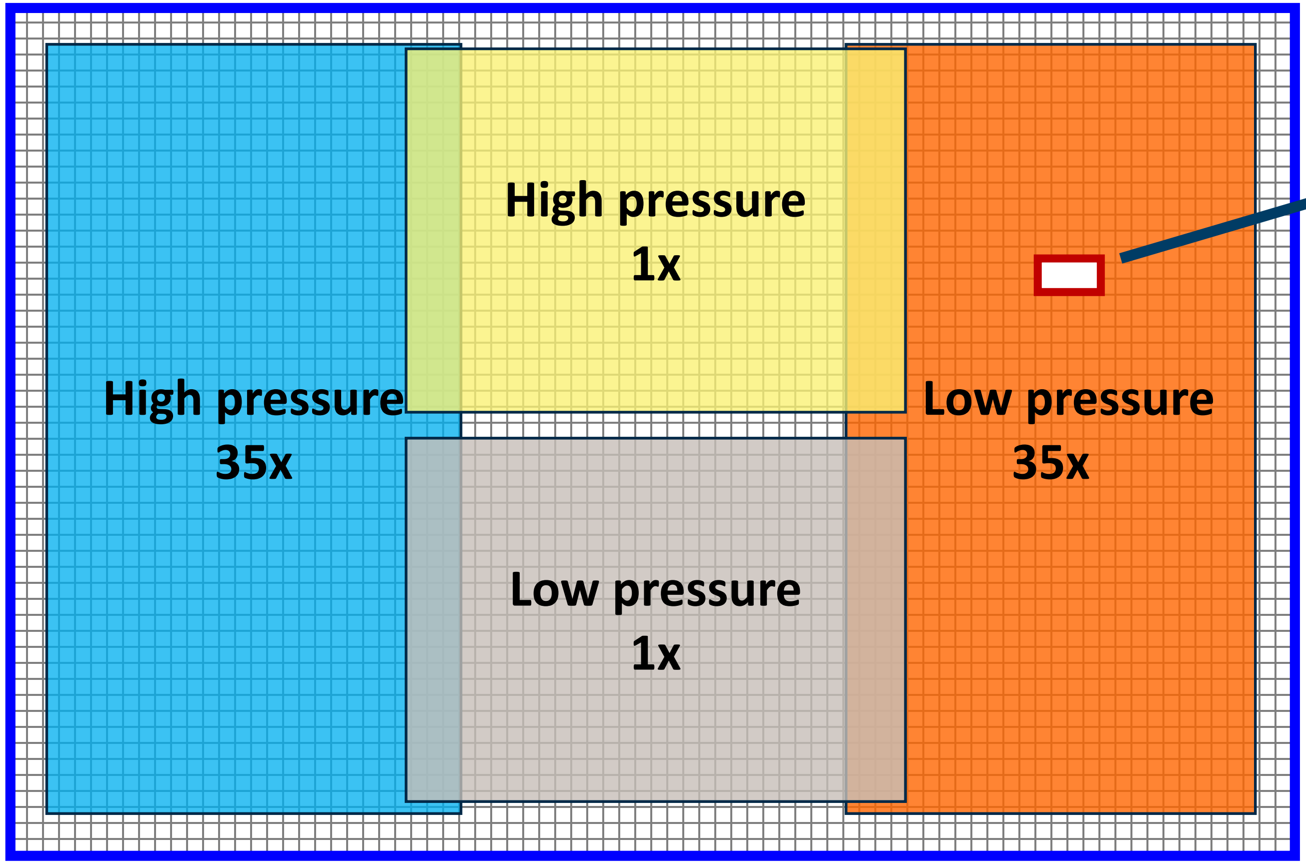
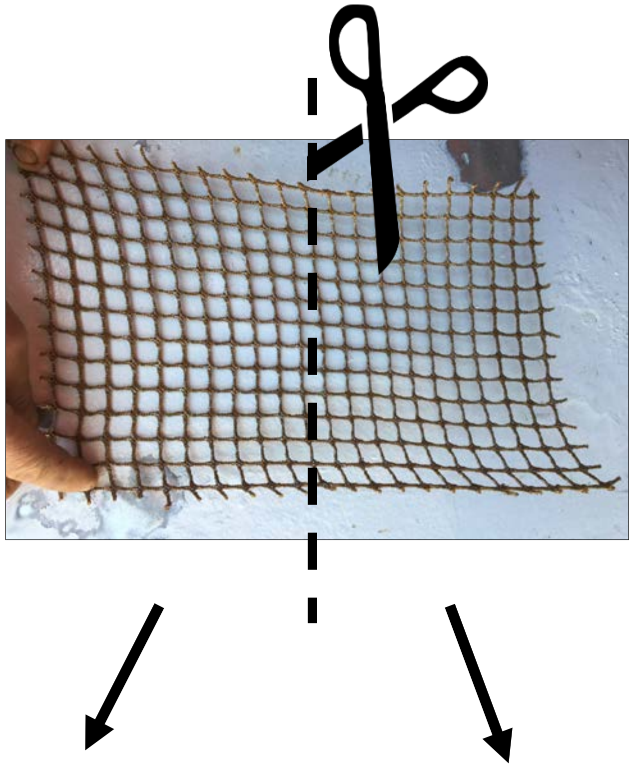
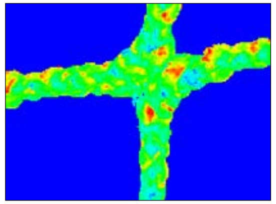
# Analysis of coating integrity and net strength



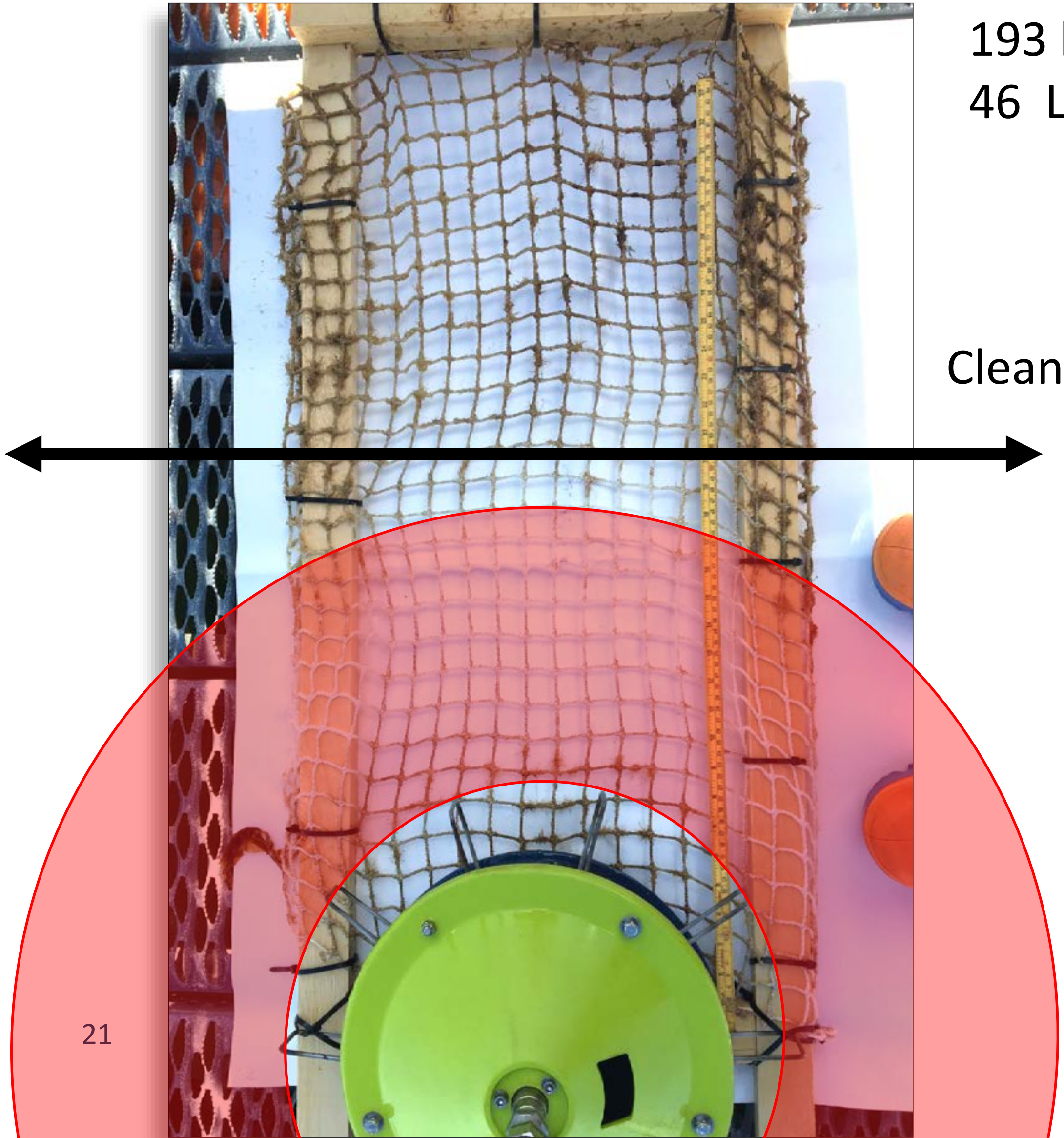



Testing of breaking strength

Analysis of coating integrity



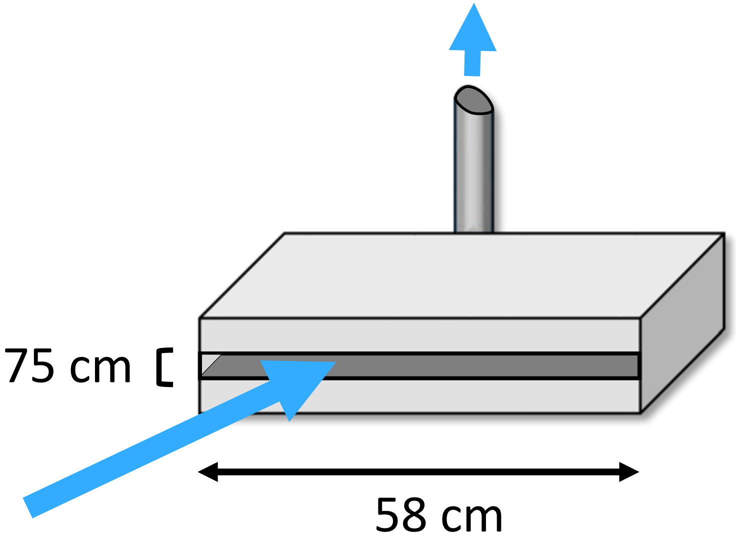
# Cavitation & Suction

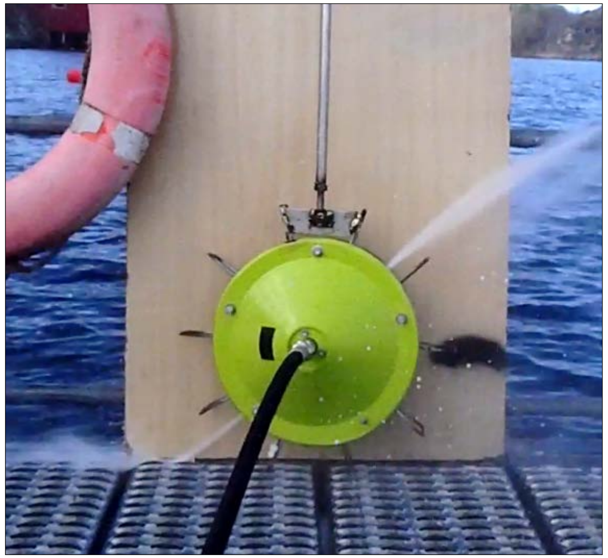


193 bar
46 L/min

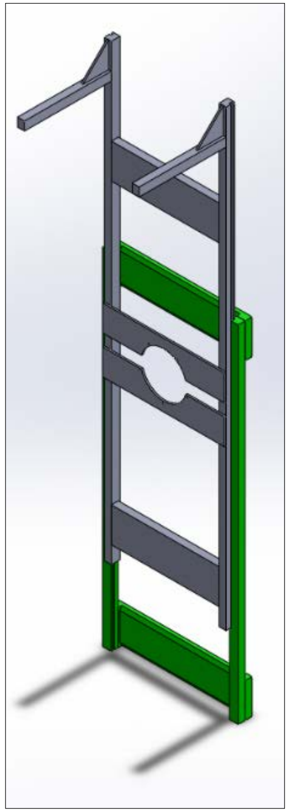
Cleaning range

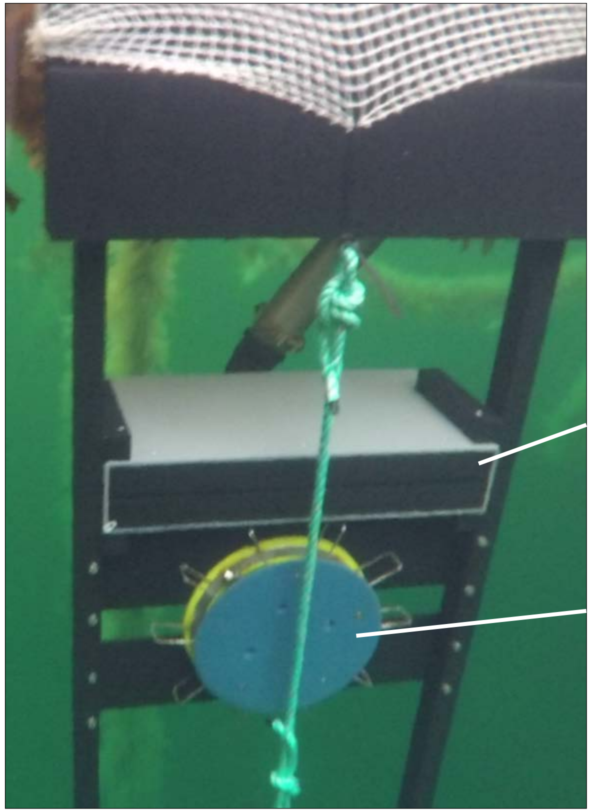
ø 90 cm



# Cavitation & Suction



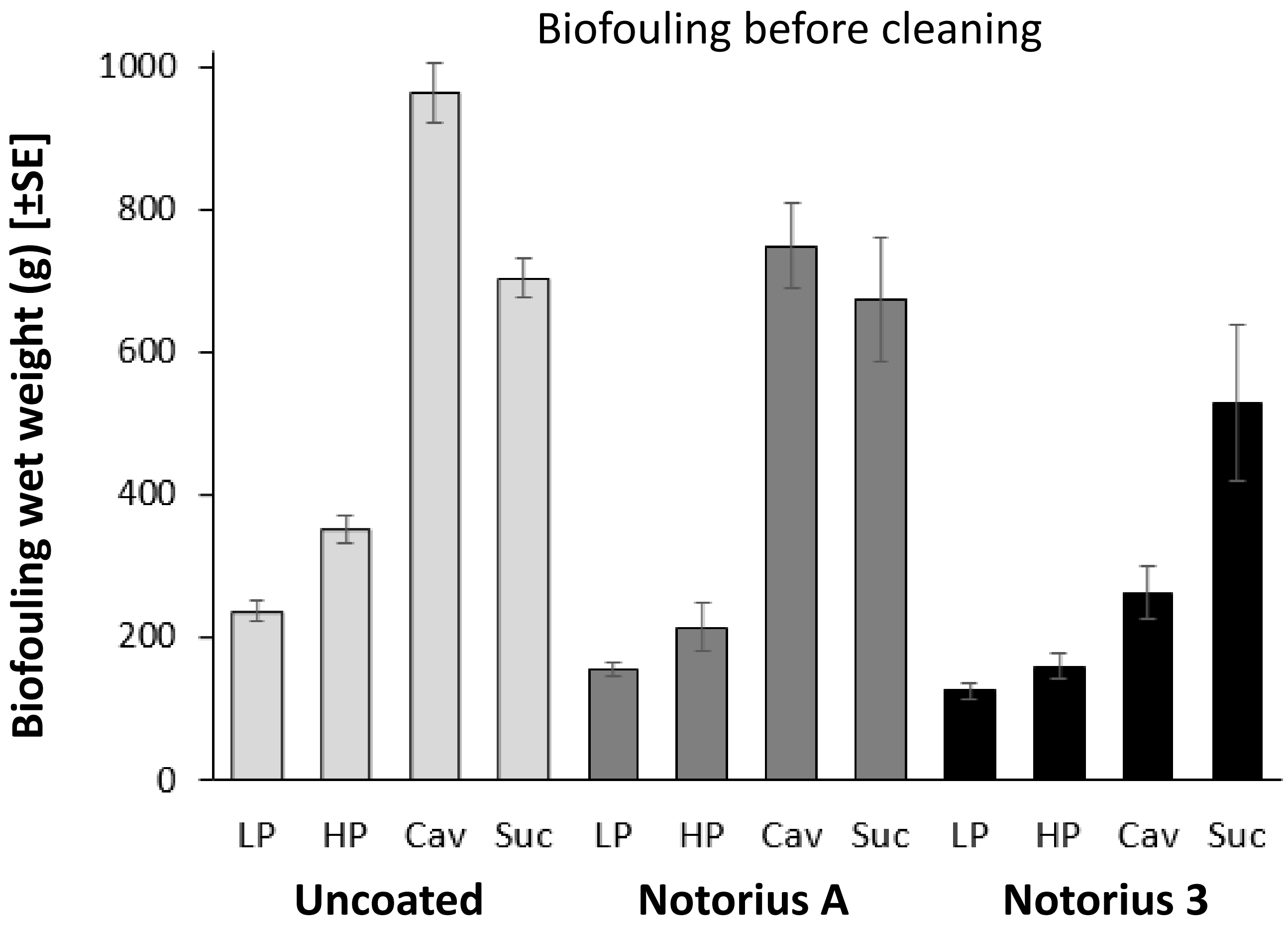


Suction cleaner

Cavitation cleaner

# WP 2: Results

# Biofouling growth




- **Challenge**: high variability in biofouling levels between samples



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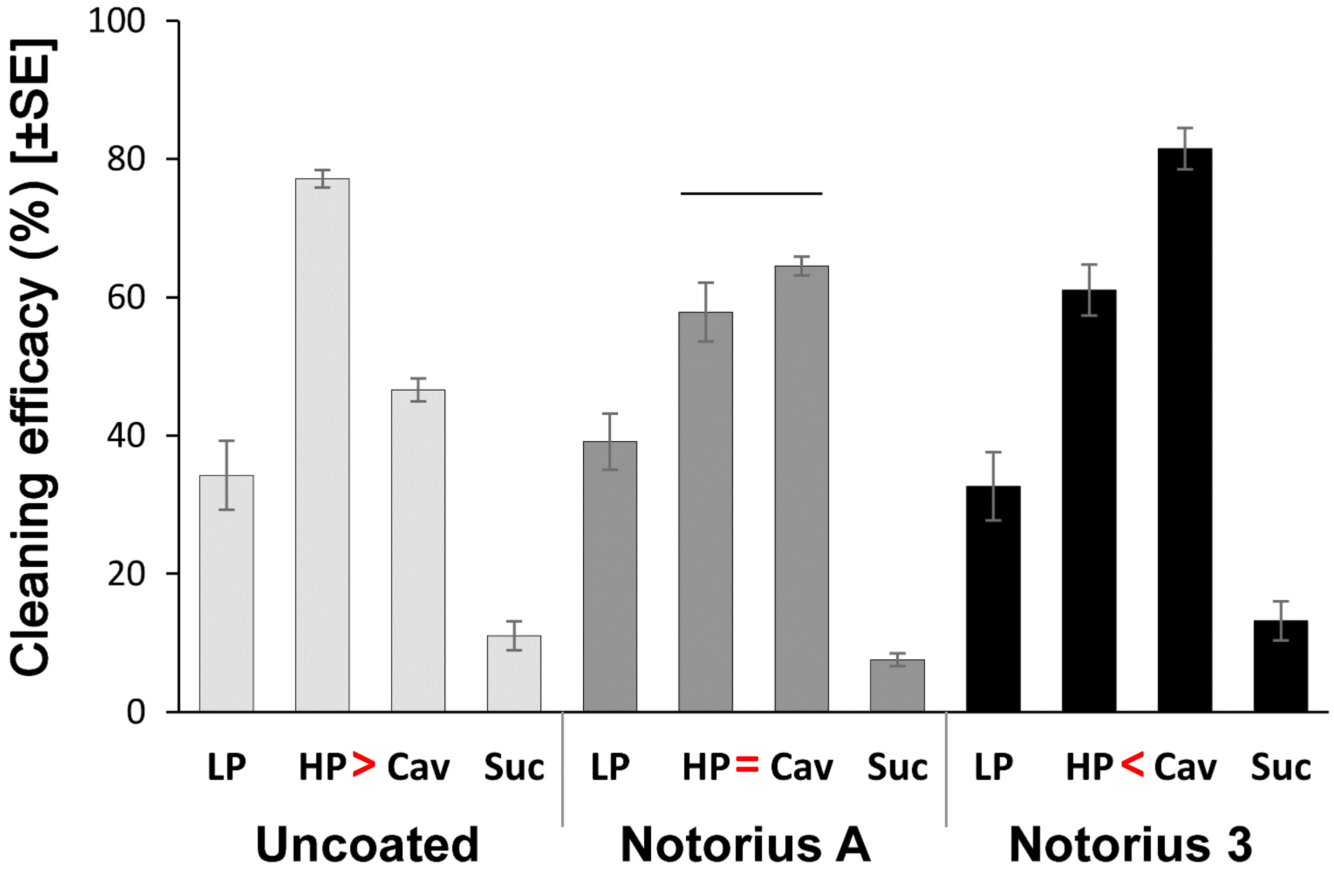
# Cleaning efficacy

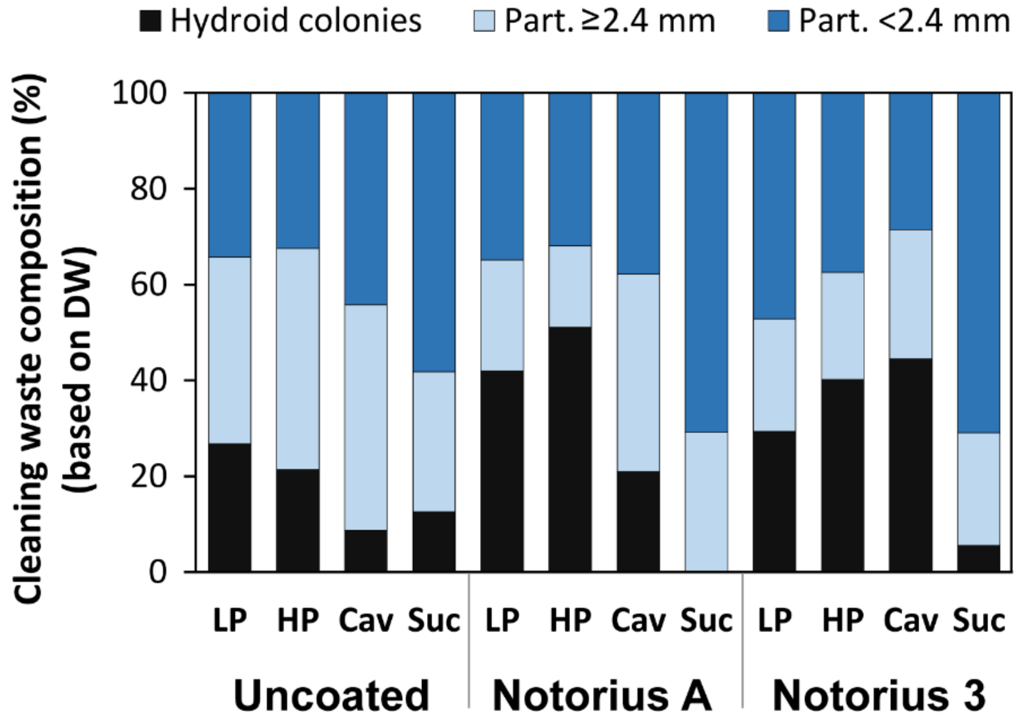



- Cavitation has similar efficacy to HP (maybe even better since there was more biofouling growth?)
- Low pressure has lower efficacy
- Suction cleaning did not work

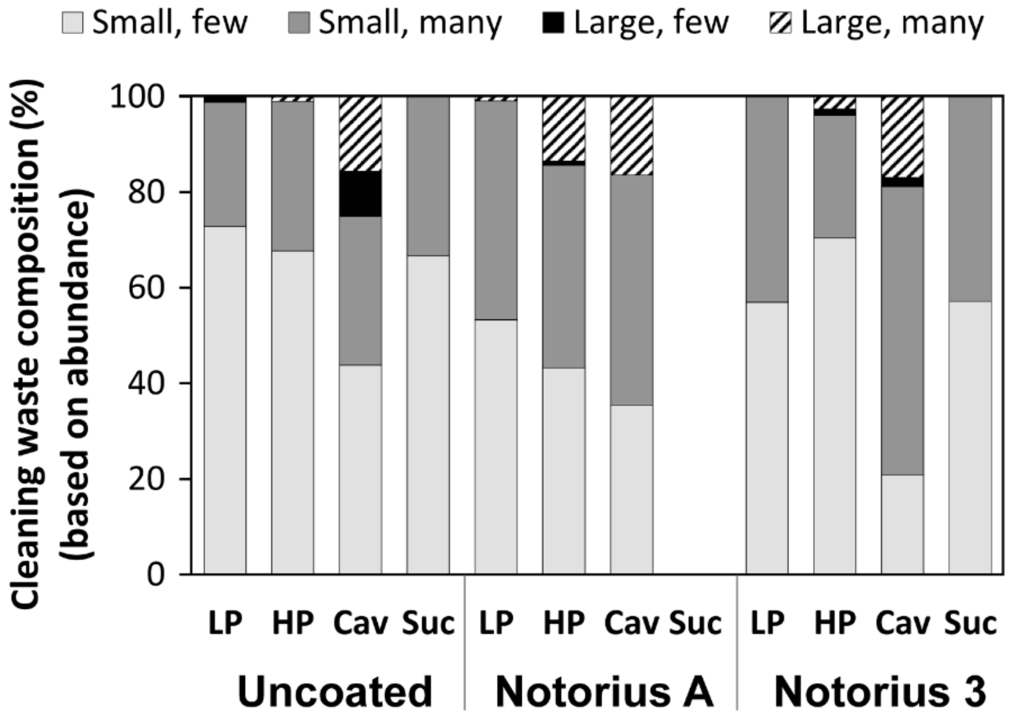
All samples differ significantly within net types,
with exception of HP and Cav when cleaning Notorius A.

# Cleaning waste particles

a) Particle category




b) Hydroid colonies




- No large differences in cleaning waste composition
- Suction cleaning waste did not contain hydroid colonies
  → low cleaning efficacy or destruction during cleaning?

! Collection was not very efficient



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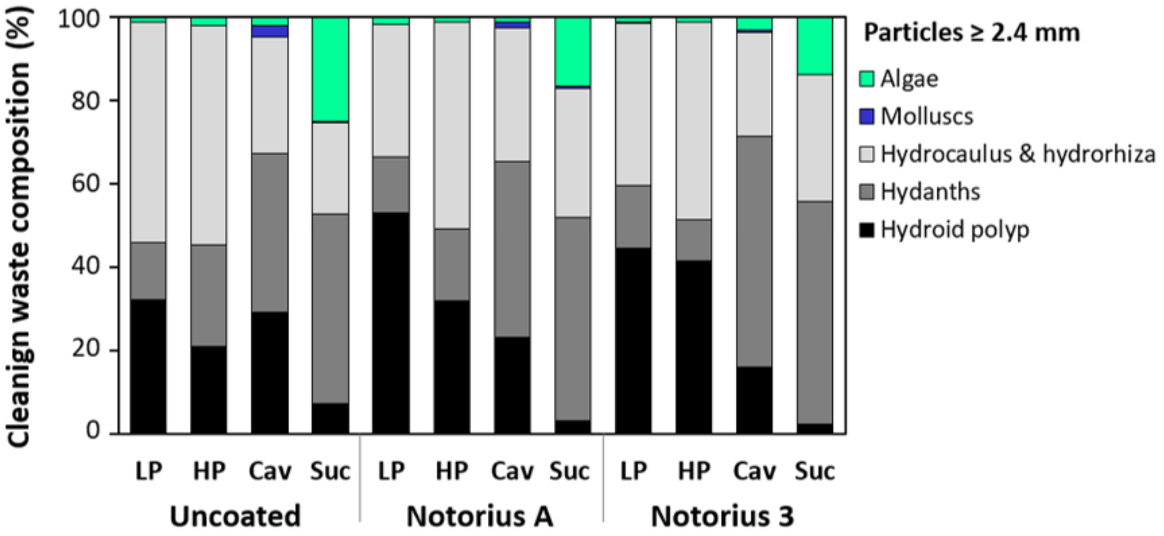
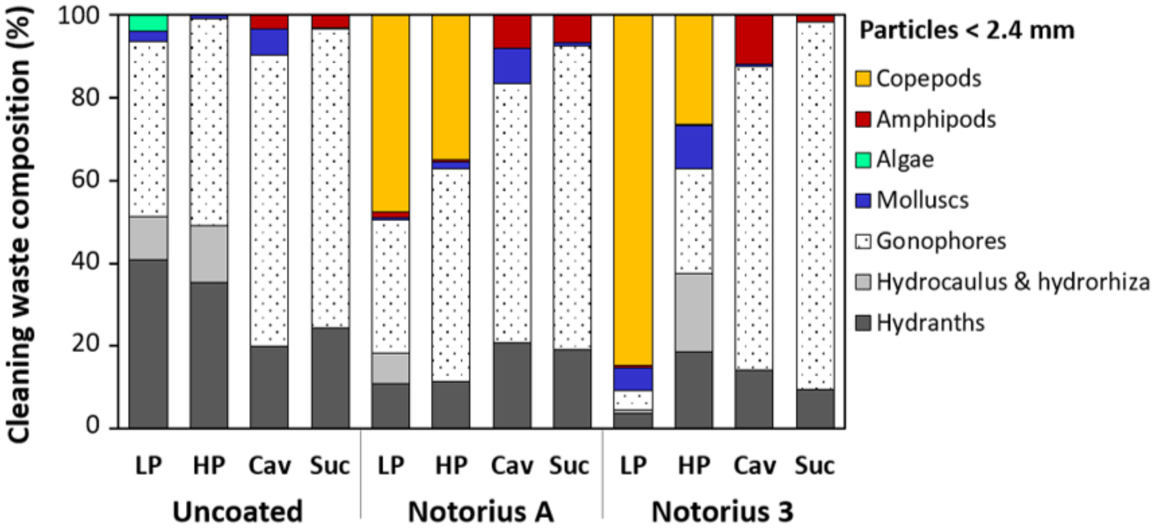
# Cleaning waste particles




- No clear patterns visible



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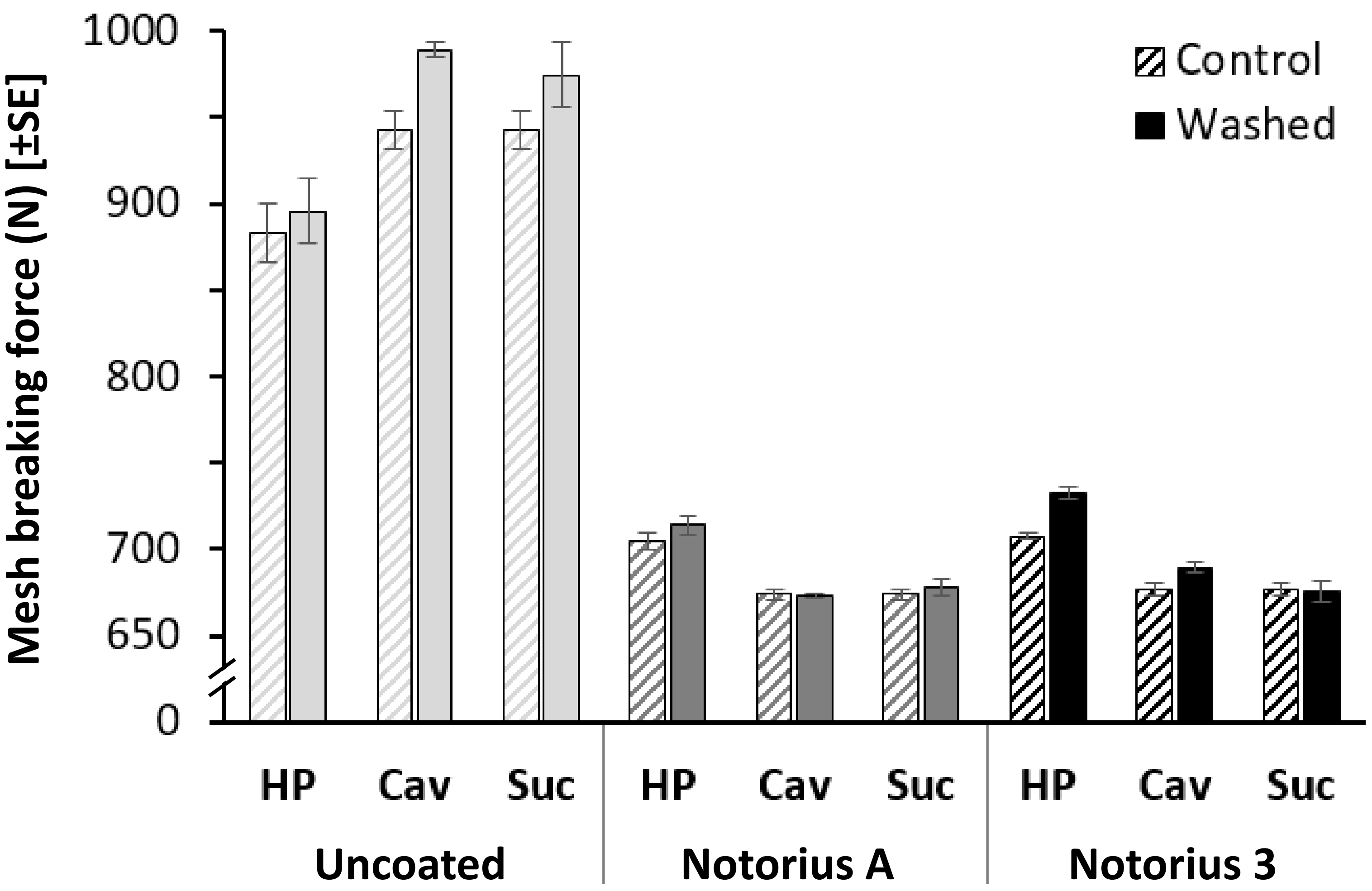
# Net strength

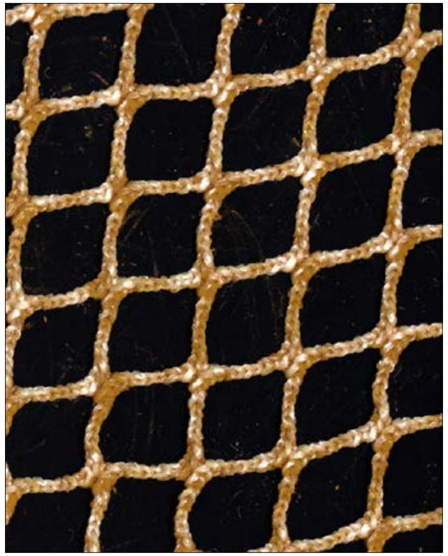



- None of the cleaning technologies reduced net strength compared to the control
- Increase in net strength connected to the removal of the coating

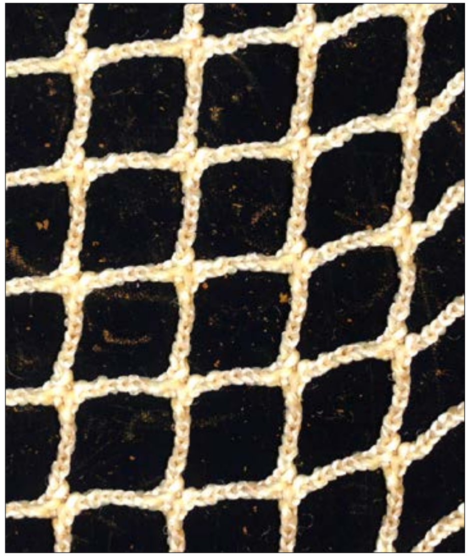
# Coating integrity

Unwashed

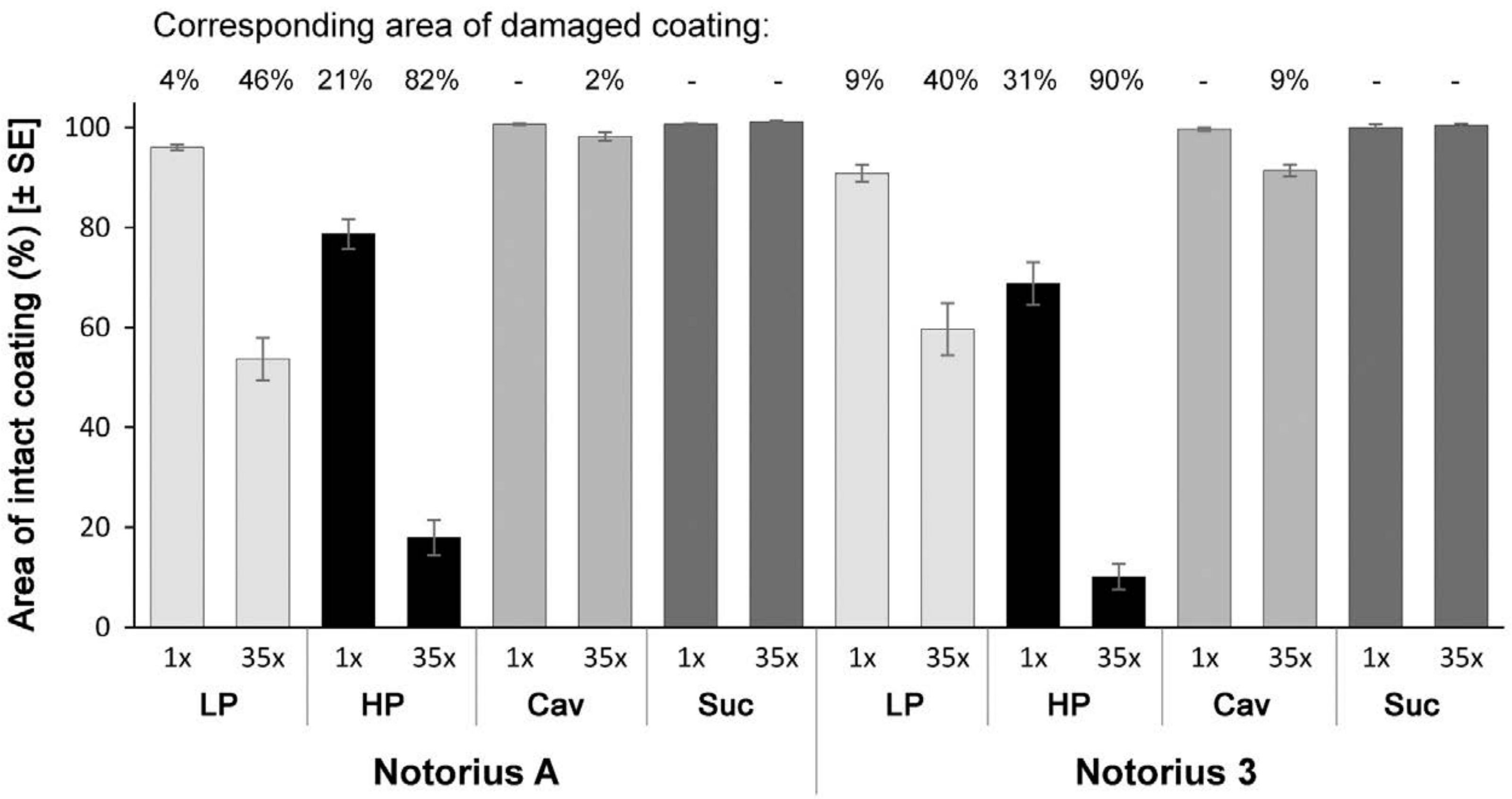
HP washed 1 x



HP washed 35 x



# Coating integrity




- HP is most damaging!
- LP does lead to damage
- Single cavitation or suction cleaning do not lead to measurable damage

Maximum damage after single cleaning:

HP: 53 % Cav: 2 %

LP: 19 % Suc: 4 %



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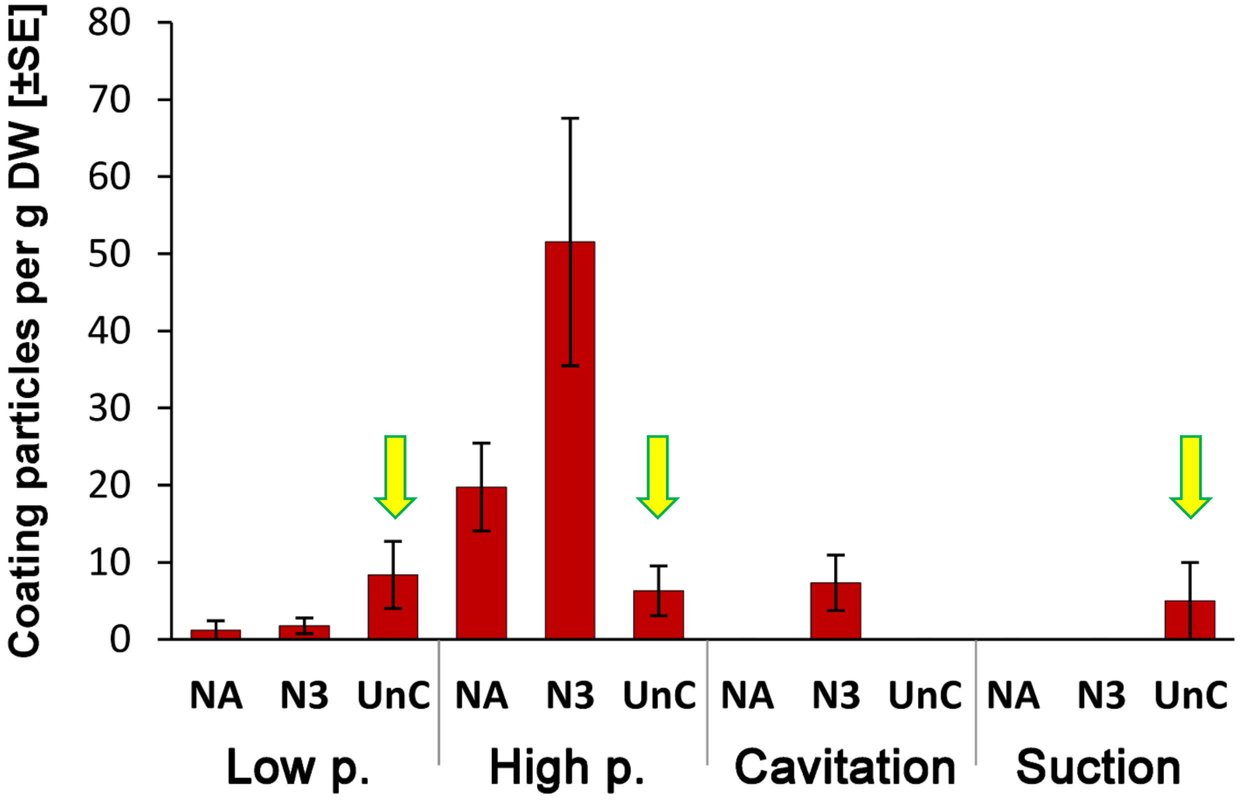
# Copper particles

➢ Most particles were collected after high pressure cleaning




Contamination during incubation?



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# WP 2 – Summary

**Induction heat**

- Interesting but needs more testing

**Cavitation cleaning**

- Similar (or better?) cleaning efficacy than high pressure cleaning
- No negative impact on net strength
- Almost no damage to the coating (Cav: 2% vs. HP: 53% max. damage after single cleaning)

**Effective and gentle alternative to high pressure cleaning!**

**Low pressure cleaning**

- Lower efficacy than high pressure cleaning
- No negative impact on net strength
- Considerable damage to the coating (max. 19%)

**Suction cleaning**

- Very low cleaning efficacy

# WP3 - Development of future net cleaners



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# Content

- WP3 – summary of findings and activities
- Recommendations for industrial up-scaling
- Results from cost-benefit analysis
- Feasibility of automation
- Recommendations for further work

# WP 3 – summary of findings and activities

WP2 results: Cavitation cleaning may offer a less abrasive yet similarly effective alternative to high-pressure cleaning → give grounds for industrial up-scaling

1) **Industrial up-scaling** of cavitation net cleaner feasible. Design, arrangement, power supply, operational methods etc. similar to existing HP cleaners.

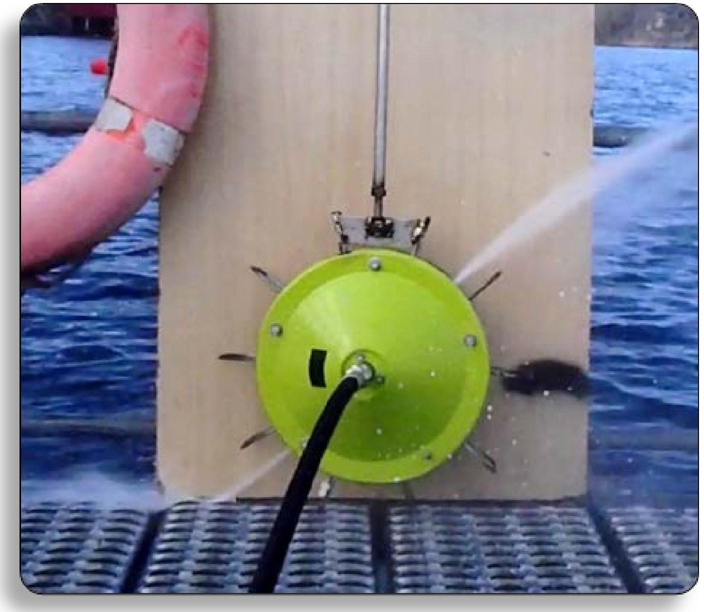
2) In the **cost-benefit analysis** cavitation cleaning is compared with HP cleaning. Results shows that cavitation cleaning will be competitive to HP cleaning.

3) **Increased level of automation** is beneficial both for existing and future cleaning technologies

# Recommendations for industrial up-scaling

# Content

- Cavitation cleaning: concept, principle and functioning
- Cavitation vs. HP cleaning: principal differences
- Industrial up-scaling: design, arrangement, cleaning speed, power requirement, operational methods



# Cavitation phenomenon

- Cavitation is a phenomenon in which rapid changes of pressure in a liquid lead to the formation of small vapor-filled cavities ("cavitation bubbles"), in places where the pressure is relatively low (e.g. due to increased flow rate)
- When subjected to higher pressure (decreased flow rate), these **cavitation bubbles collapse** and can generate an intense shock wave.

$$\frac{1}{2}\rho_L v^2 + p = const.$$

Bernoulli's equation

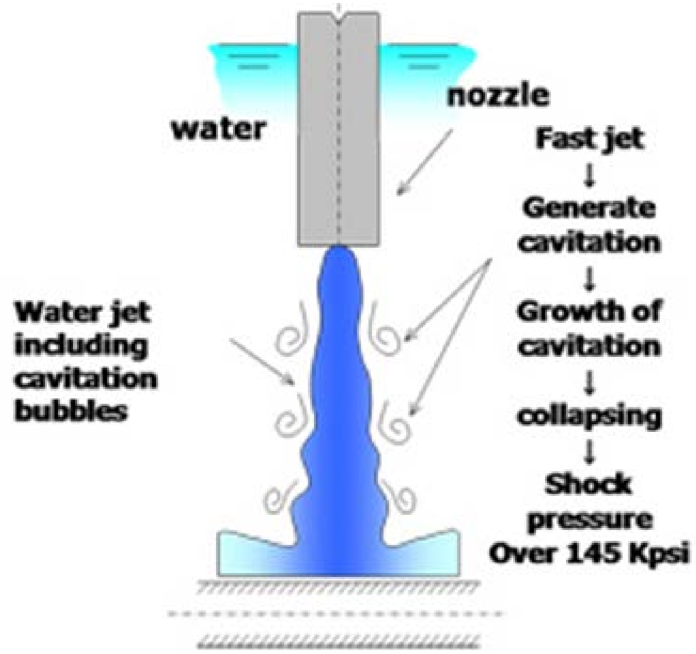



Figure: Mitsubishi Nuclear Energy Systems

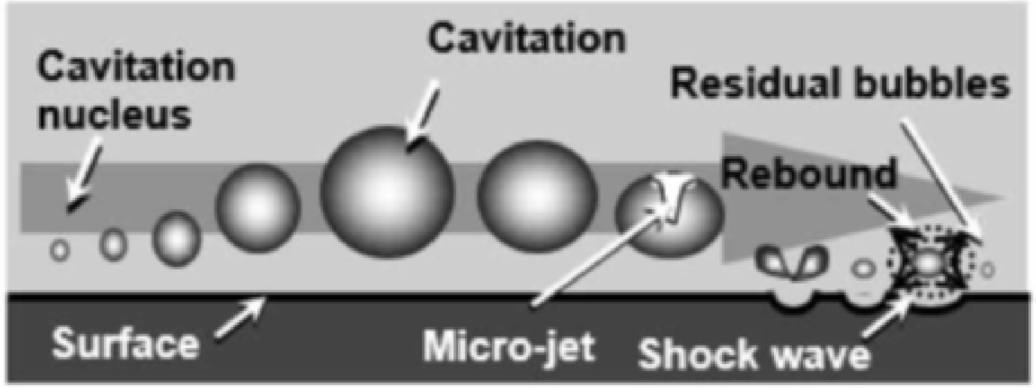



Figure: Soyama, 2017



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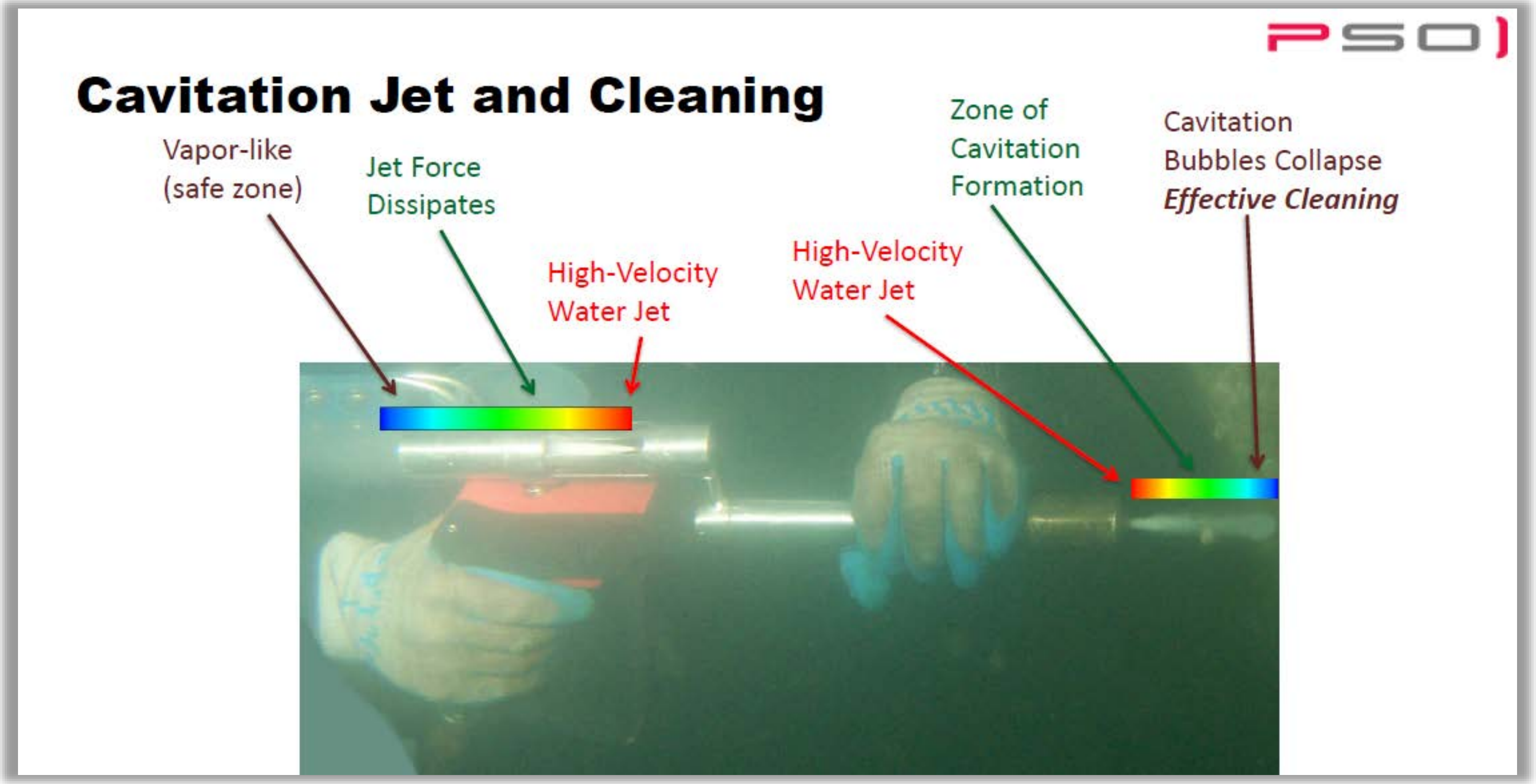


- If the cavitation bubbles collapses near to a solid surface, this micro shock wave may cause undesirable erosion of metallic materials, but this release of energy may also be used for cleaning.
- By using specially designed nozzles in a high pressure water jet system it is possible to control the formation and collapse of the cavitation bubbles.

# Cavitation intensity and cleaning efficiency

- The cavitation intensity (i.e. cleaning efficiency) depends on several parameters, the key factors are the **nozzle geometry/configuration** and **pressure differences**.
- The **cavitation number** has a strong influence on the cavitation intensity (distribution and strength of the bubbles) and influences the jet spreading angle.
- Cavitation depends on the actual pressure in the flowfield, hence there is no single empirical value for below which cavitation is guaranteed and above which it is not possible.

$$\sigma = \frac{p - p_v}{\frac{1}{2}\rho_L v^2} = \frac{p_2 - p_v}{p_1 - p_2} \approx \frac{p_2}{p_1}$$

Cavitation number: $\sigma$
Upstream pressure: $p_1$
Downstream pressure: $p_2$


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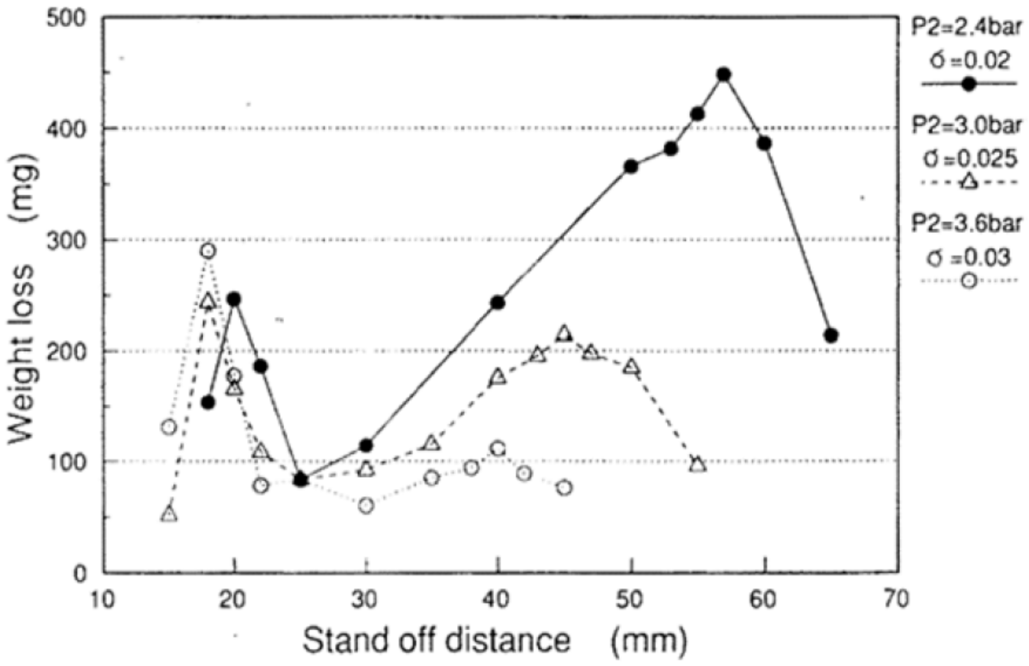
# Cavitation intensity and cleaning efficiency

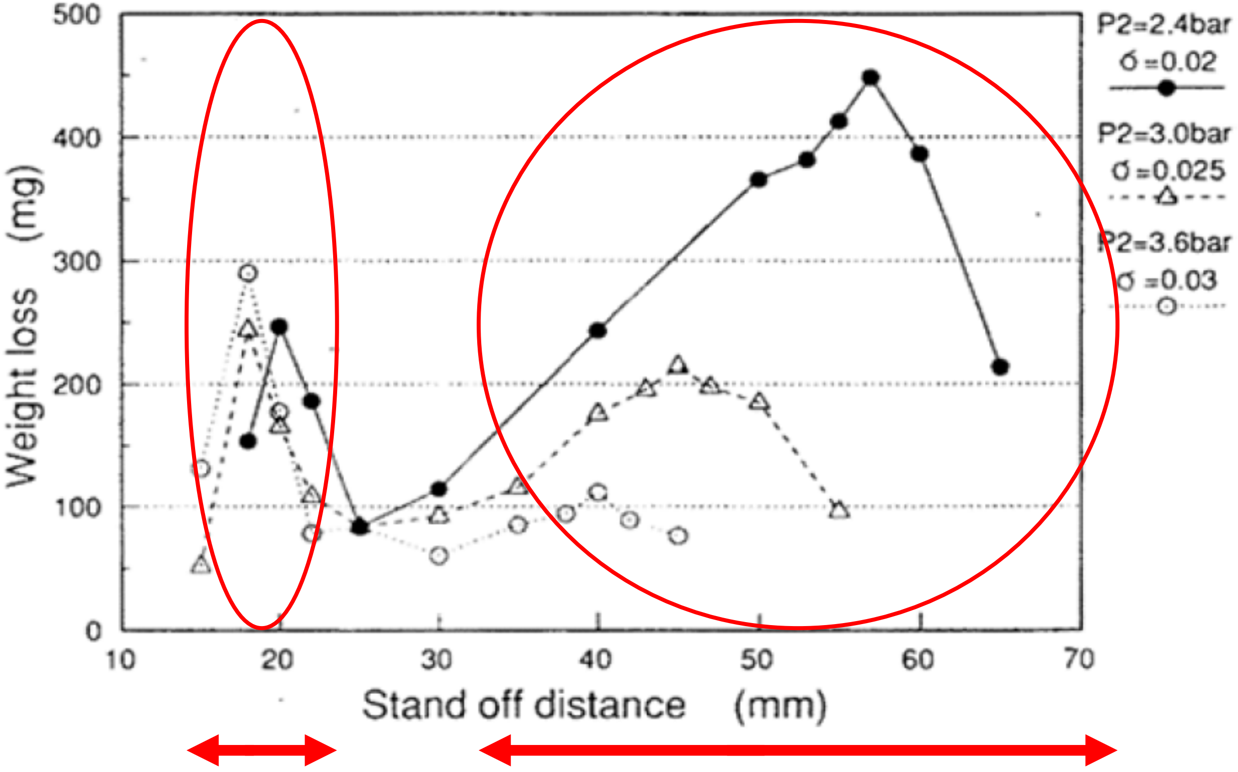
$$\sigma = \frac{p - p_v}{\frac{1}{2}\rho_L v^2} = \frac{p_2 - p_v}{p_1 - p_2} \approx \frac{p_2}{p_1}$$

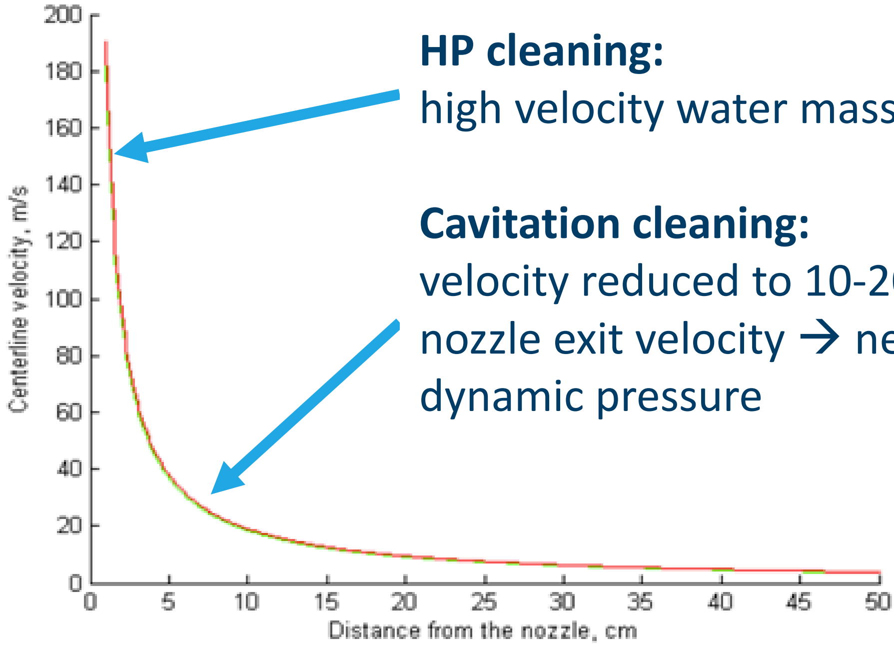
Cavitation number: $\sigma$
Upstream pressure: $p_1$
Downstream pressure: $p_2$




- Cavitating flow with a **small cavitation number means that the cavitating region is large**, and a large cavitation number signifies that the cavitating region is reduced or has disappeared.
- **Cavitation intensity decreases with increasing water depth.**
- PSO cavitation cleaner suitable for 0-50 meter water depth.

# Cavitation vs. HP cleaning – stand off distance




**HP cleaning:**
high velocity water mass impacts

**Cavitation cleaning:**
velocity reduced to 10-20% of nozzle exit velocity → negligible dynamic pressure

Suitable region for HP water jet cleaning (water mass impacts)

Suitable region for cavitation cleaning (cavitation impacts)

**Cavitation cleaning gives longer reach and larger cleaning range compared to HP cleaning using similar pressure and flow rate.**



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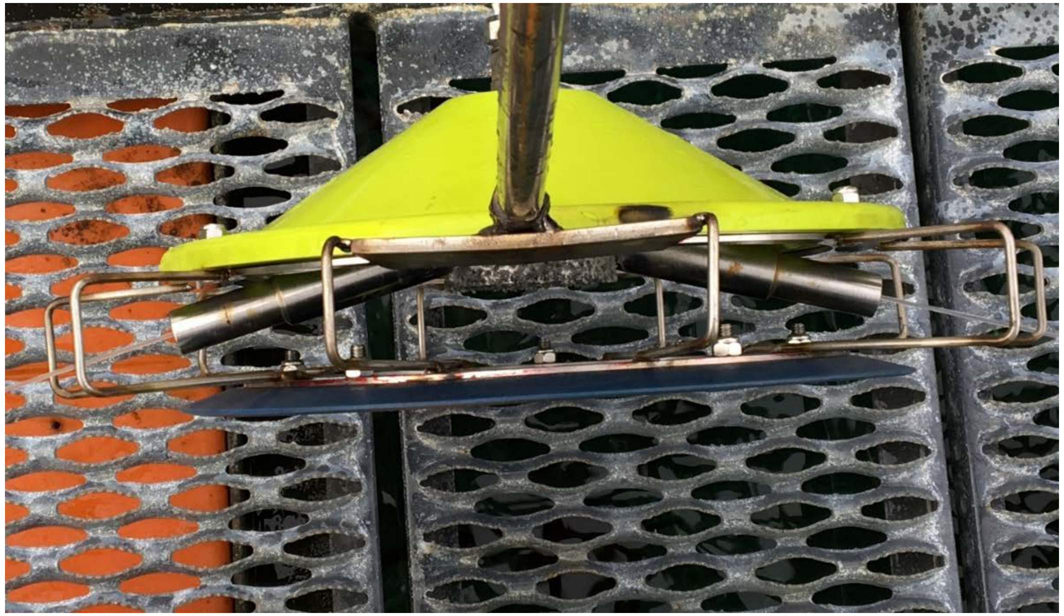
# Cavitation vs. HP cleaning – stand off distance

- Cavitation cleaning is based on similar pressure and flowrate as HP cleaning
- At the nozzle exit, the water jet effect is similar to HP water jet
- To prevent undesirable water jet effects (e.g. wear of coating) a minimum separation needs to be ensured.
- Alternative concepts for maintaining safe distance and/or  encasing nozzles is possible





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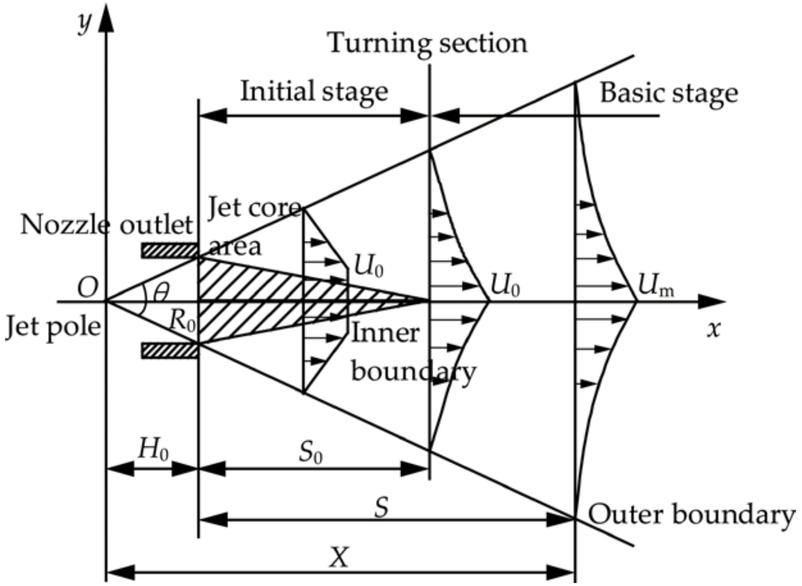
# Cavitation cleaning – wear/erosion

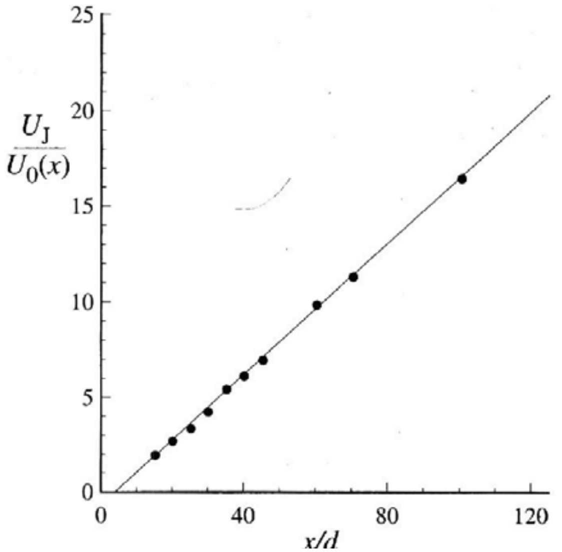
- The velocity of the microjet formed during cavitation bubble collapse is affected by the properties of the surfacea gainst which it is collapsing. **"Softer" surfaces lead to less violent collapse and less erosivity**

# Cavitation vs. HP cleaning

- Effective HP jet distance is 5-8 x nozzle diameter, and decays very rapidly

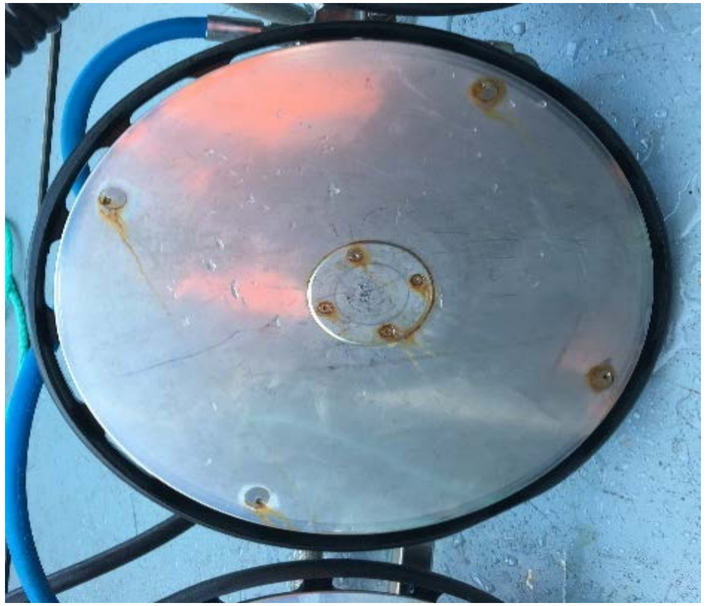



Schematic diagram of the submerged water jet (Wen, Chen, & Campos, 2018)

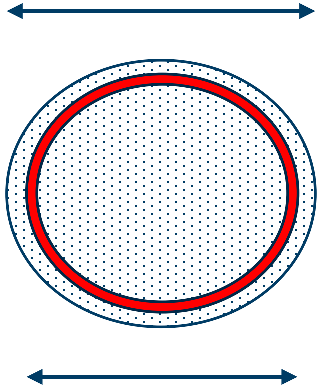



The variation with axial distance of the mean velocity along the centerline in a turbulent round jet (Pope, 2000)

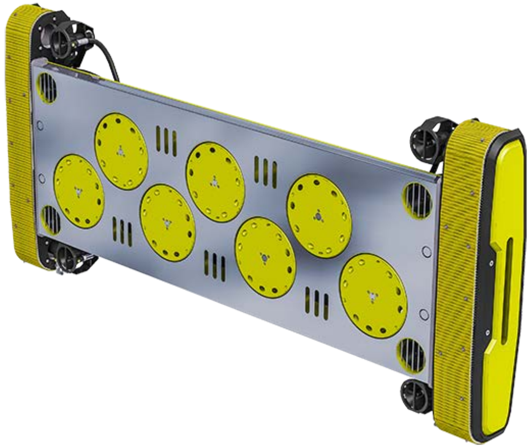
# Cavitation vs. HP cleaning



39 cm – diameter HP disk



~ 37 cm – effective cleaning width, red circle indicates cleaning range

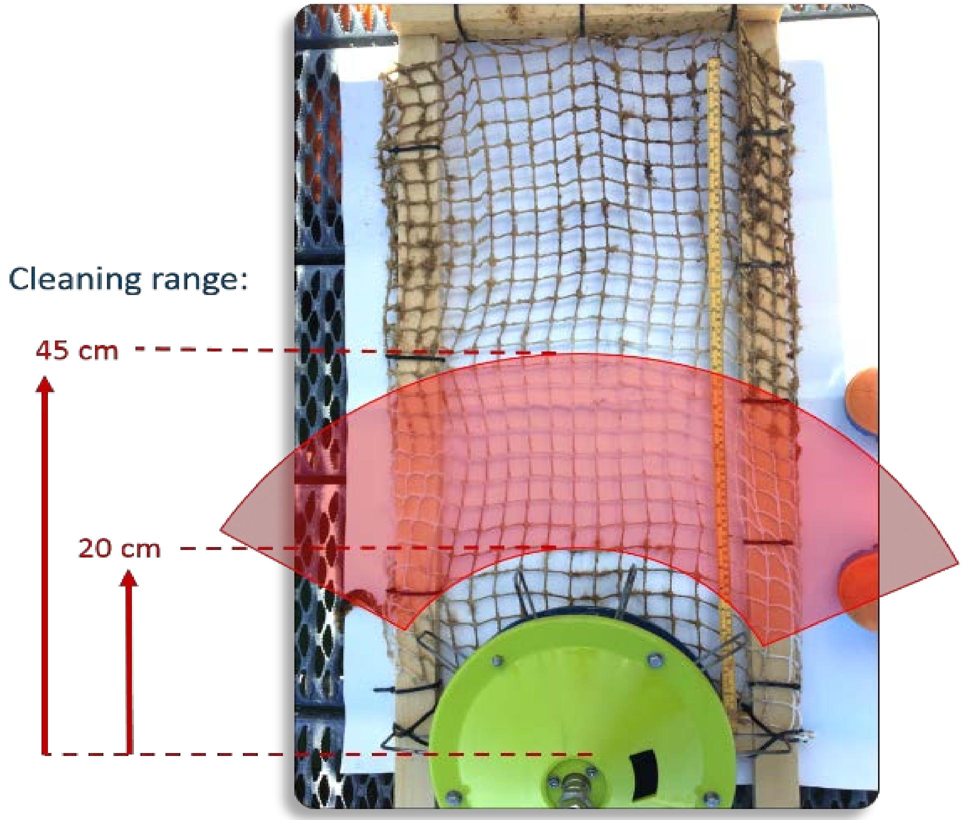


HP disk typical arrangement:

- 2-4 nozzles per disk
- Nozzles 45° to the disk surface in tangential direction, providing rotational speed, 750-1500 rpm

# Cavitation cleaner - effective cleaning range

- Jet distance too short: cavitation bubbles not fully developed and lead to weak cavitation effects.
- Jet distance too long: cavitation bubbles are fully developed, but burst before they reach the materials' surface.
- Need for optimizing the distance from nozzle to material surface.
- PSO indicates an effective cleaning range 5-12cm from nozzle (56 cm width) for 0-50m water depth





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# Cavitation cleaner: cleaning range & width

Cleaning width 56 cm (PSO)

Cleaning width 90 cm (test results WP2)

Cleaning range 4-29 cm (test results WP2)

Diameter disk – 32 cm

Cleaning range 5-12 cm (PSO)

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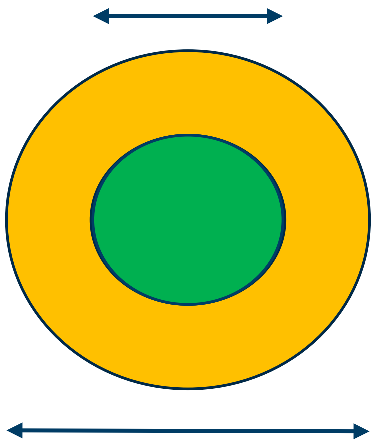
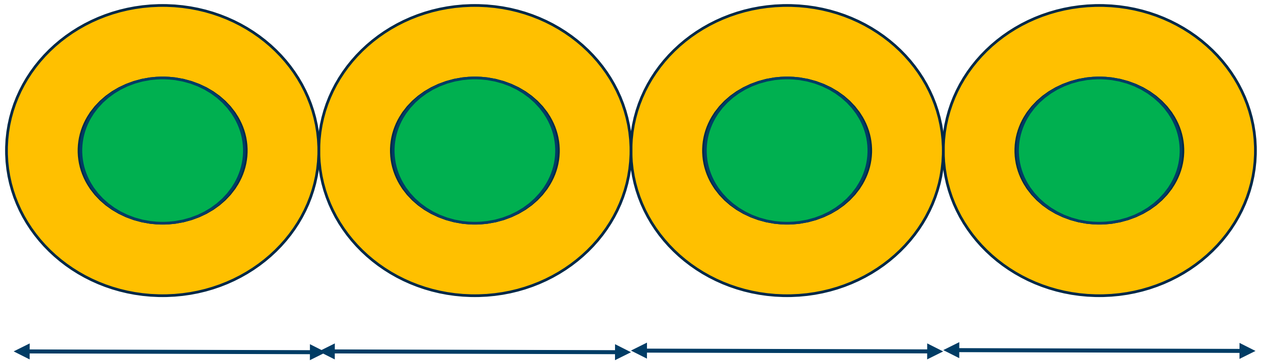
# Cavitation cleaner: proposed arrangement

- Cavitation intensity decreases with increasing water depth, but the biofouling intensity also decreases with depth.
- 60 cm cleaning width assumed in this study
- Proposed arrangement:

32 cm – diameter disk



60 cm effective cleaning width



60 cm effective cleaning width per disk,
2,4m total cleaning width

# Cavitation cleaner: cleaning speed

Assessment or optimization of cleaning speed has not been studied.
However, execution of WP 2 tests indicates:

- Cavitation cleaner: 15 $m^2$/min (1 disk)
- HP cleaner: 27-47 $m^2$/min (6 disks)
- Cavitation cleaners also have larger cleaning range
- **It is assumed that cleaning speed of cavitation cleaners could be equal to or better than HP cleaners.**



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# Cavitation cleaner: power requirement

Cleaning width, arrangement and power requirement for selected HP net-cleaners

| Model | Cleaning width | No of disks | No of nozzles | Power requirement |
|---|---|---|---|---|
| RONC 7 (MPI AS) | 1,9m | 7 | 21 | 218 kW |
| FNC 8 (Sperre AS) | 2,6m | 8 | 24 | 150 kW |
| Stealth cleaner (Ocein AS) | 2,3m | 7 | 21 | N/A |
| Manta Net Cleaner (Stranda Prolog) | 2,6m | 7 | 21 | N/A |

WP 2 prototype: 16 kW.

Proposed rig with 4 disks: 64 kW

→ **Potential for more than 50% reduction in energy consumption**

# Cavitation cleaner: operational methods

- All existing operational methods (hoist rig, belt rig, free flying) are considered feasible to cavitation based net-cleaners.





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# Results from cost-benefit analysis

# Results from cost-benefit analysis

Results from cost-benefit analysis indicates the cavitation cleaning could be competitive compared to high-pressure cleaning:

- **Reduced total cleaning costs –** less cleaning events
- **Reduced energy consumption -** larger efficient cleaning area
- **Potential for cleaning of copper-treated nets in-situ in compliance with the ASC standard** - based on minimal damage to coating from cavitation cleaning.

# Results from cost-benefit analysis, cont.

- **Better cleaning efficiency** – larger efficient cleaning area gives better efficiency at transitions and bends.
- **Time consumption**: moving speed similar to HP cleaning. Net with intact coating easier to clean?
- **Equipment cost**: pump system etc. similar to HP cleaning. Design, arrangement and operational method similar to HP cleaning.
- **Fish welfare**: reduced number of cleaning events, reduced exposure to biofouling waste.

# Results from cost-benefit analysis, cont.

No significant difference found between cavitation cleaning and HP cleaning for other/non-quantifiable factors;

- Wear and damage to net
- Maintenance of equipment/downtime
- Operational methods
- Feasibility of automation
- Collection of cleaning waste

# Cost-benefit analysis – reduced cleaning costs

- **65% total cost reduction is foreseen**
- Intact coating may give increased cleaning intervals, reduced number of cleaning events and reduced cleaning costs.
- Results from WP1;
  - average time to first cleaning 3,2 months for new coating
  - 14 cleaning events in average per production cycle (w/coating)
- 6 - 1 (change from smolt net) = 5 cleaning events


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# Cost-benefit analysis – energy consumption

- Larger efficient cleaning area gives approx. 50% reduced power requirement.
- Service vessel contributes to energy consumption
- Example: cleaning 3 nets per day / 1 hour transit per day
  - HP cleaning: ~1000 kWh per net per cleaning event (vessel 400 kWh + HP cleaner 600 kWh)
  - Cavitation cleaning: ~650 kWh per net per cleaning event (vessel 400 kWh + cavitation cleaner 250 kWh)

# Fish welfare

Possible factors that may affect fish welfare:

- **Biofouling waste**: Neither cavitation nor HP cleaners have the possibility for efficient collection of biofouling waste. However, cavitation cleaning may give fewer cleaning events and hence **reduced exposure to biofouling waste**.
- **Movement** of water (water jets and propellers) and moving equipment: similar type of exposure for both concepts
- **Noise:** cavitation generates high-frequent noise – above hearing range of Salmonoids?



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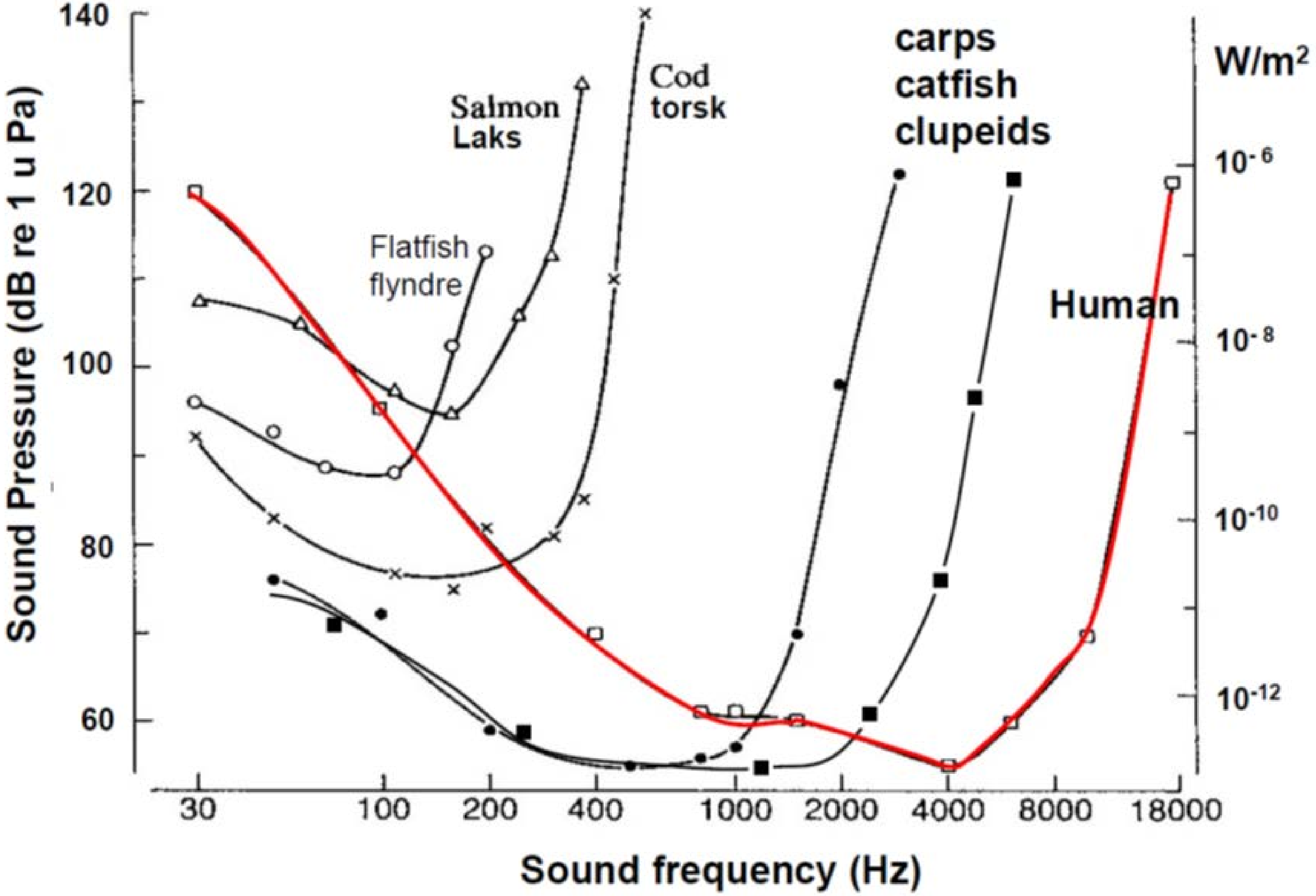
# Fish welfare – the hearing of Salmo salar



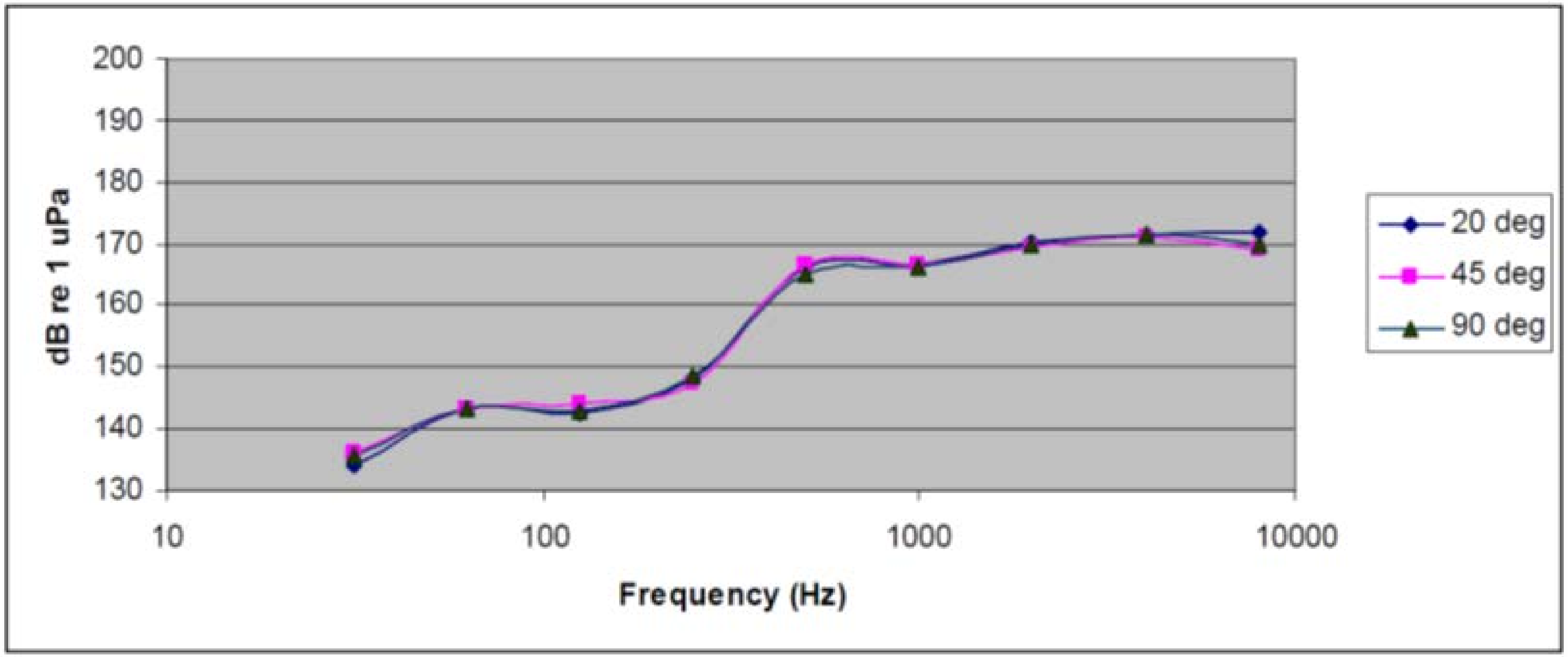

Auditory sense for different species of fish compared to humans (Karlsen, 2010)

**The Salmon has a low sensitivity and a narrow frequency band compared to other species**

# Fish welfare – noise levels in aquaculture

- Noise level in open sea net-pens?
- Noise level in RAS (Recirculating Aquaculture Systems): long term effects of sound levels up to 149 dB tested on Rainbow trouts
- This sound level is not likely to effect growth rate or survival rate
- 149 dB assumed to represent maximum sound level in RAS

# Fish welfare – noise from cavitation cleaners




Cavitation cleaner – sound level and frequency, 5m water depth (Cudahy et al., 2010)



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# Feasibility of automation

# Feasibility of automation

Increased level of automation, applied to existing net cleaning technology, has the potential to:

- Increase effectivity and quality of cleaning
- Detect holes and damages to net
- Higher level of automation / fully autonomous vehicles requires alternative cleaning technology (e.g. low energy net cleaners)

# Recommendations for further work

# Recommendations for further work

- Full scale test of cavitation cleaner
- Cleaning efficacy at increasing water depth
- Cleaning of copper-treated nets in-situ in relation to the ASC standard
- Low-pressure cleaning and damage to coating
- Noise levels from cavitation cleaners

# WP4 - The future of biofouling control in aquaculture

# Requirements for future biofouling control strategies

- Efficient prevention of biofouling growth
- Not harmful to the fish
- Environmentally benign
- Safe for the user
- Cost-efficient
- Sustainable (long lasting and recyclable)

# Current biofouling management

## Prevention

- Copper coatings
- Copper metal nets
- Alternative biocides

➢ Not efficient enough for regions with high biofouling pressure
➢ Impact on non-target species
➢ Environmental pollution
➢ Sustainability…?

## Removal

- Net cleaning
    - ➢ Labour-intense and costly
    - ➢ Fish health risk
    - ➢ Some emerging technologies
- Net exchange
    - ➢ Risk of fish escapes
    - ➢ Cleaning on land
    - ➢ Re-coating

# Options for future biofouling management strategies

**1**

Efficient antifouling without cleaning

**2**

Antifouling combined with intermittent cleaning

**3**

Grooming of nets without antifouling

# Strategy 1: Efficient antifouling without cleaning

**Description**

- Prevents ALL biofouling
- No cleaning needed

**Advantages**

- No biofouling = No cleaning
  - ➢ No impact on fish health
  - ➢ No coating abrasion
- Lasts at least one grow-out cycle
- Predictable cost

**Challenges**

- Biofouling is highly variable = high likelihood of resistance
- Efficient AF is often highly toxic, also to non-target organisms (→ TBT)
- Drifting (dead) material can still occlude the net

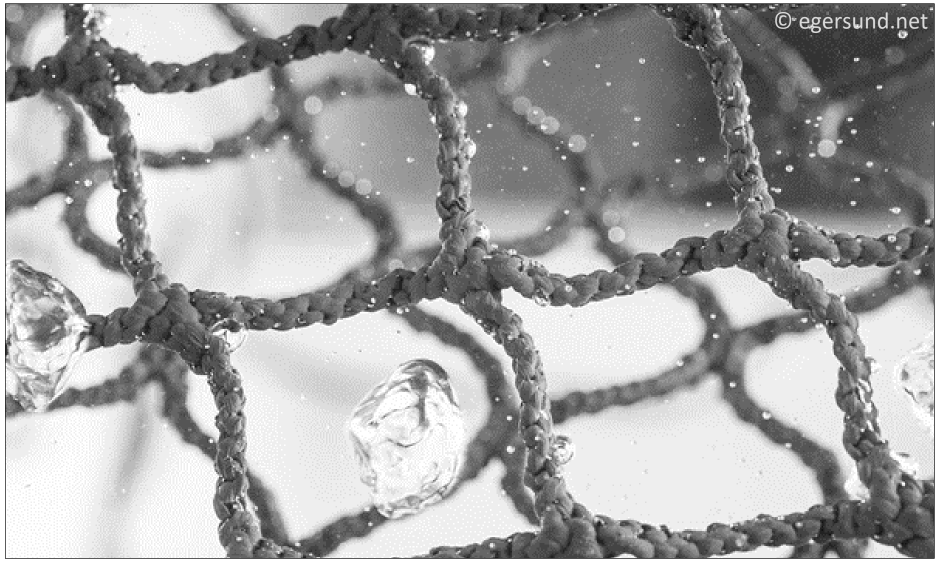
# Strategy 1: Efficient antifouling without cleaning

**Current status**

- Current AF products offer insufficient protection (may work in low-intensity regions)
- Environmental & sustainability requirements not yet met

**Research priorities**

- Development of novel antifouling coating with
  - high efficacy (at least full grow-out cycle)
  - environmentally benign biocide
  - good leaching control
  - high robustness



# Strategy 2: Antifouling combined with intermittent cleaning

**Description**

- (Non)Biocidal net/coating that prevents/delays most biofouling
- Robust net/coating
- Gentle cleaning w/o abrasion
- Collection of cleaning waste

**Advantages**

- Reduced cleaning frequency
- Reduced cleaning waste emission
  - ➢ No/reduced impacts on fish health
  - ➢ No/reduced coating abrasion
- Lasts at least one grow-out cycle

**Challenges**

- Variability of biofouling and toxicity of potent antifouilng coatings
- Biofouling collection technically challenging

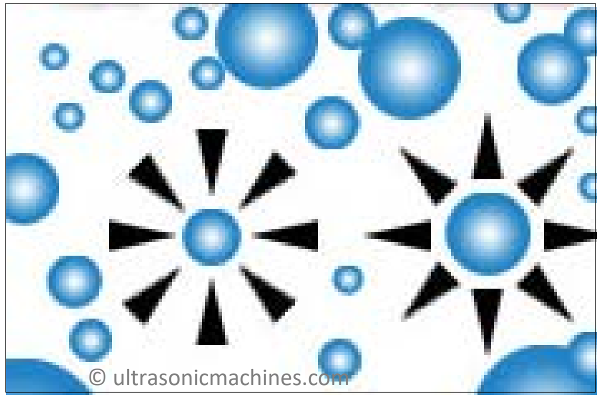
# Strategy 2: Antifouling combined with intermittent cleaning

## Current status

- Copper alloy metal nets potential option but need environmental & sustainability assessment
- Potential cleaners are low-pressure/high volume or cavitation based – need further assessment

## Research priorities

- Development of efficient AF net or coating (non-biocidal or benign biocide)
- Development of gentle net cleaners that collect waste
- Evaluation of potential use of collected biofouling (fertiliser, biofuel, …?)
- Cooperation between coating and net cleaning technology manufacturers → most efficient and robust combination.



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# Strategy 3: Grooming of nets without antifouling

**Description**

- Regular, frequent grooming of nets
- Uncoated nets or nets coated w/ protective coating (UV, abrasion) and good cleanability

**Advantages**

- Prevention of biofouling growth
  - ➢ No release of cleaning waste
    = no impact on fish health
  - ➢ Initial biofouling easier to remove
    = no abrasive cleaning necessary
- No environmental contamination

**Challenges**

- Cost- and energy efficiency of high frequency cleaning

# Strategy 3: Grooming of nets without antifouling

**Current status**

- Durable nets (EcoNet, Dyneema) and coatings available
- Net grooming technology developed but not validated or automated

**Research priorities**

- Development of net materials/coatings that are
  - easy to clean
  - abrasion & UV resistant
- Development of foul-release coatings
- Novel net cleaning technology that
  - operates autonomously
  - has high cleaning efficacy
  - is energy-efficient
  - has no mechanical impact on nets/coatings
  - does not impact the fish


# Which strategy to choose?

| Efficient antifouling without cleaning | Antifouling combined with intermittent cleaning | Grooming of nets without antifouling |
|---|---|---|

**Local biofouling pressure**

**Compliency with standards**

**Cost efficiency**

# Is there a future for net cleaning?

**Current motivation: cleaner fish**



**Health and welfare challenges**

**Presence of biofouling has no influence on behaviour**

(Leclercq et al. 2018)

**Cleaner fish may benefit from biofouling**

- Increased delousing motivation (Eliasen et al. 2018)
- Indications for increased skin health (Patursson 2019)

**Use of cleaner fish may be prohibited…?**

**Less frequent cleaning?**

**Biofouling related health risks**



Leclercq et al. 2018. Aquaculture 495:1-12.; Eliasen et al. 2018. Aquaculture 488:61-65.; Patursson 2019. Sea lice conference, Trondheim.

# Biofouling –
# current challenges and future developments

# What's left to do…

# Finalising the project

- Official project end: 30. June 2019
- Reporting to the research council: 31. August 2019
  - Economic report (→ in-kind contribution from partners)
  - Scientific report
- Planned publications after the project time:
  - Aquaculture Europe conference, Berlin, October 2019
  - AP2: "Testing of novel net cleaning technology for finfish aquaculture", *Biofouling*
  - AP3: Popular science article in Kyst.no / iLaks
  - AP4: "Future biofouling management in Norway's salmon aquaculture", *Aquaculture Environment Interactions* or similar.

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Teknologi for et bedre samfunn