Portable MS-UV Sensing Platform for Water Quality in Aquaculture

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AQUA MMS

SEVENTH FRAMEWORK PROGRAMME

Global Food Security

- **Global food security** : the greatest challenge of the 21st century?

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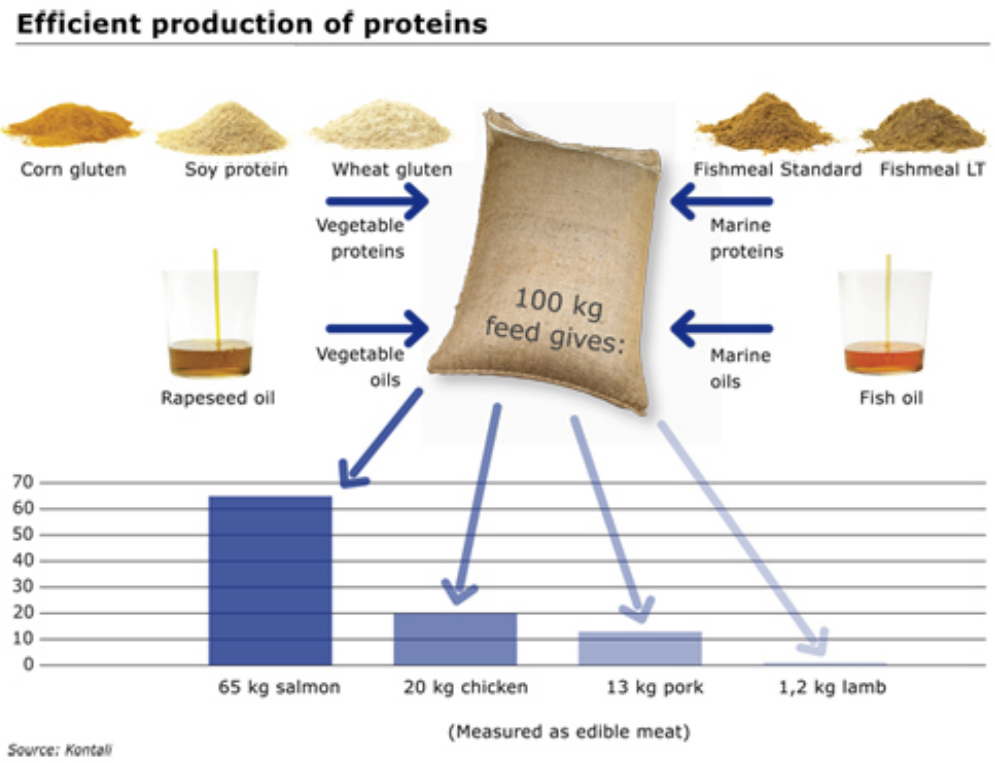
- Expanding populations, increased competition for land and water, climatic and economic change: major changes in food production.

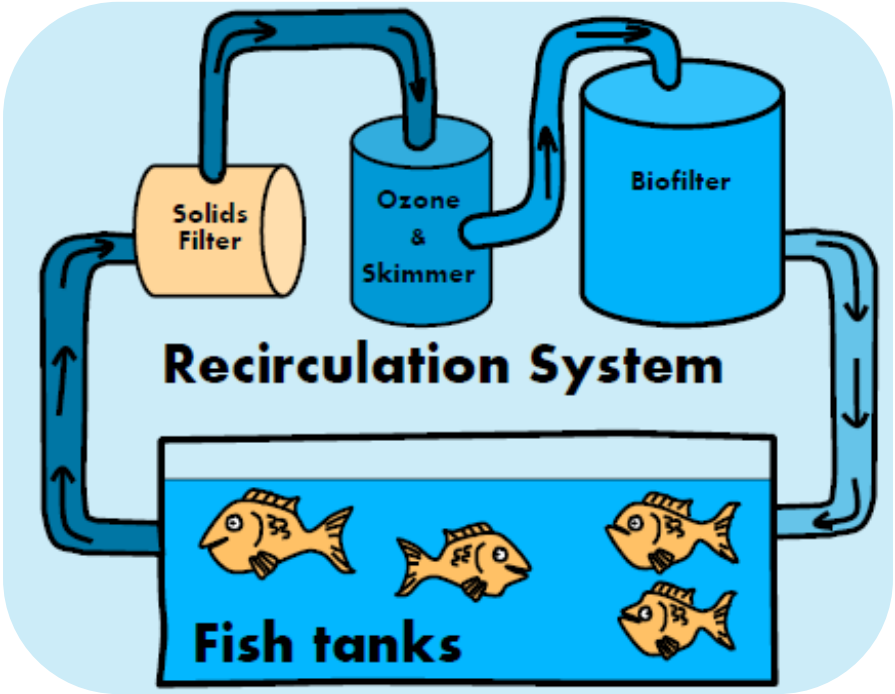
Aquaculture: The Solution?

- **Global Food Security** depends upon sustainable animal production.
- **Fish:** high food conversion ratio.
- **70%** of the world's fish stocks are fully exploited, over exploited or depleted.
- **Aquaculture** is the fastest growing agricultural sector with production rates averaging 8% growth per year (over the last 20 years).



Aquaculture: The Challenges

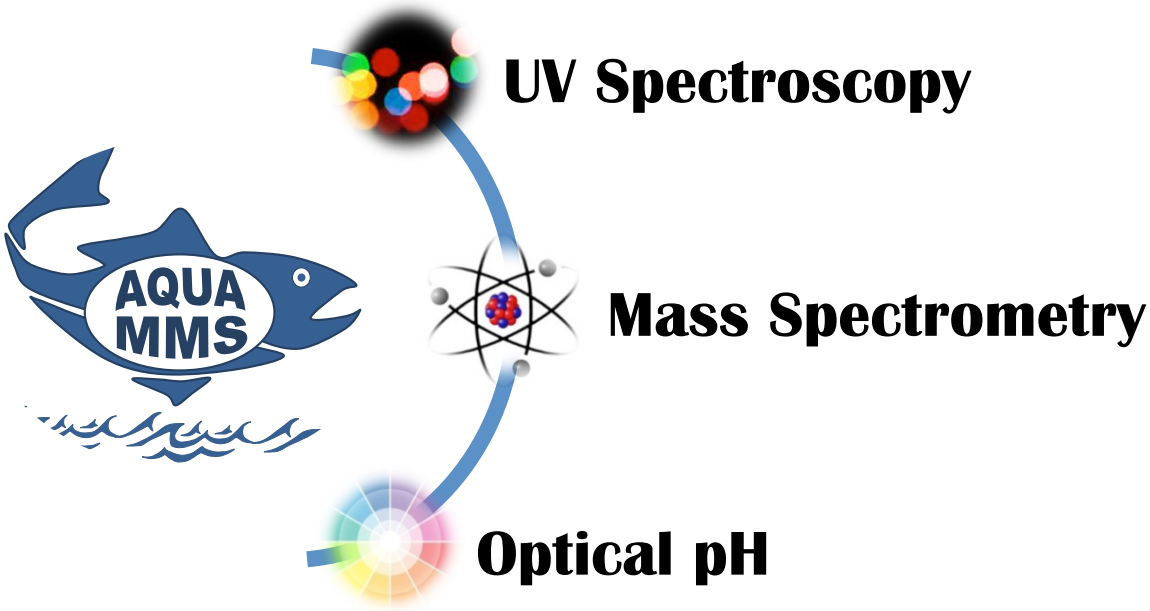
- **Recirculating aquaculture systems (RAS):** treat enormous volumes of low-grade wastewater, conserving both water and land by maximizing production in a closed loop.



- RAS need improved methods of **real time monitoring of water quality** to optimise growth conditions, avoid fish stress and product contamination.
- Novel **Sensors** and **Instrumentation** are becoming increasingly important

Aquaculture Multi-Monitoring System (AquaMMS)

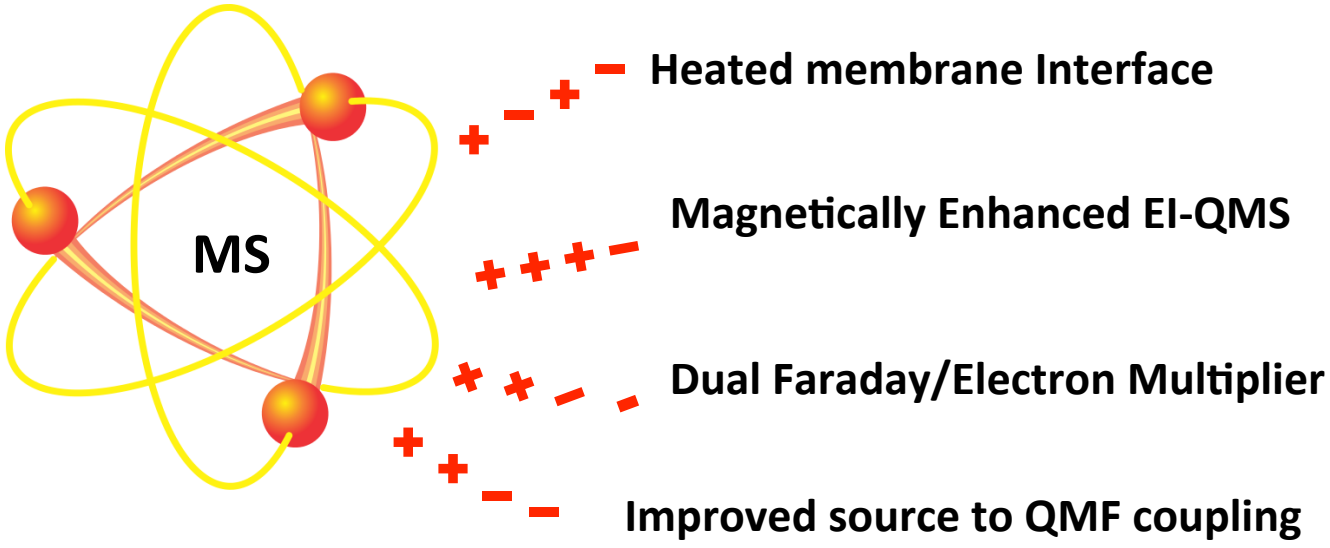
AquaMMS: $3.6m project delivering a novel **multi-sensing** system which combines 3 orthogonal analytical techniques on a single portable platform.



Aim: robust, onsite, portable multi-sensing platform, to **monitor online a wide range of vital water quality parameters simultaneously** for the land-based aquaculture industry.

AquaMMS: Mass Spectrometer

AquaMMS system has the following features to allow real time *in situ* monitoring of organics and dissolved gases in water.



Membrane Inlet Mass Spectrometry

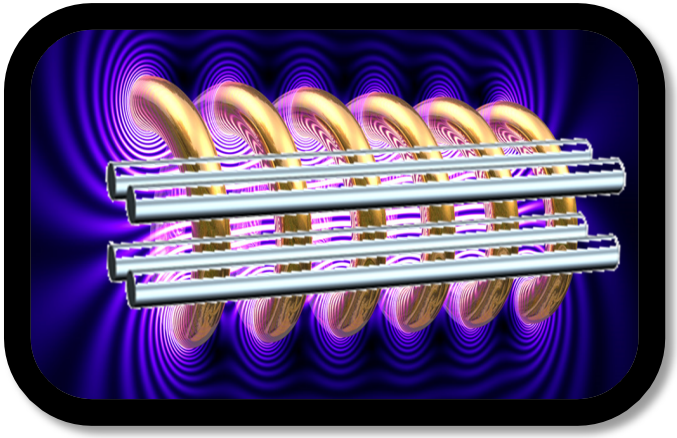
Key MS Specifications:

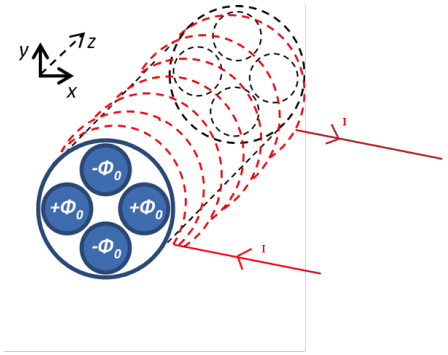
- ❑ Quadrupole mass spectrometer with axial magnetic field enhancement

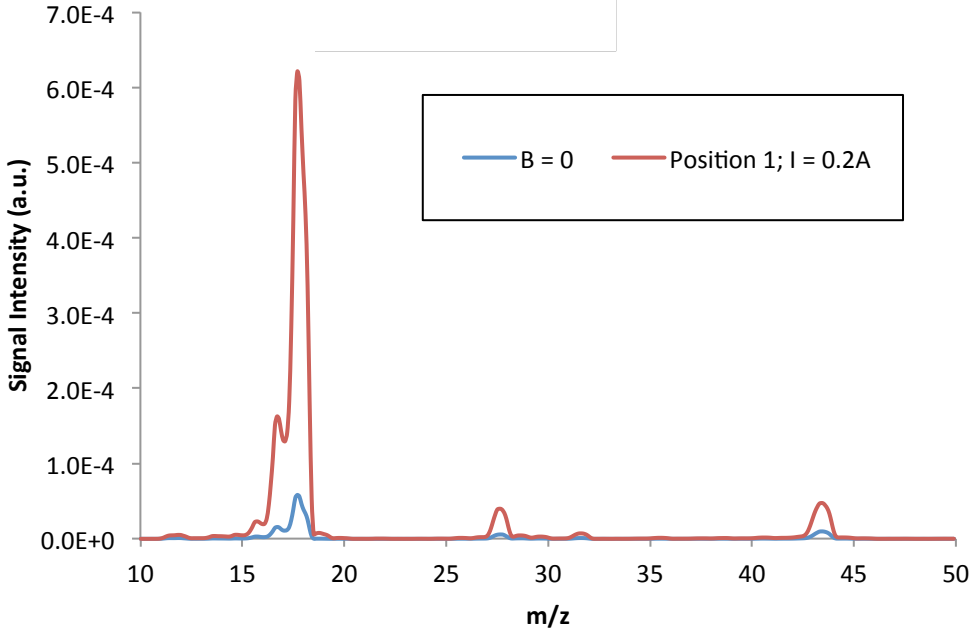
Membrane Features:

- ✓ Double membrane interface
- ✓ Silicone tubing ~0.4 mm wall thickness, length 5 cm
- ✓ Operation at elevated temperatures (up to 60°c)
- ✓ Membrane failure protection system
- ✓ Membrane temperature control system

Magnetically Enhanced QMS





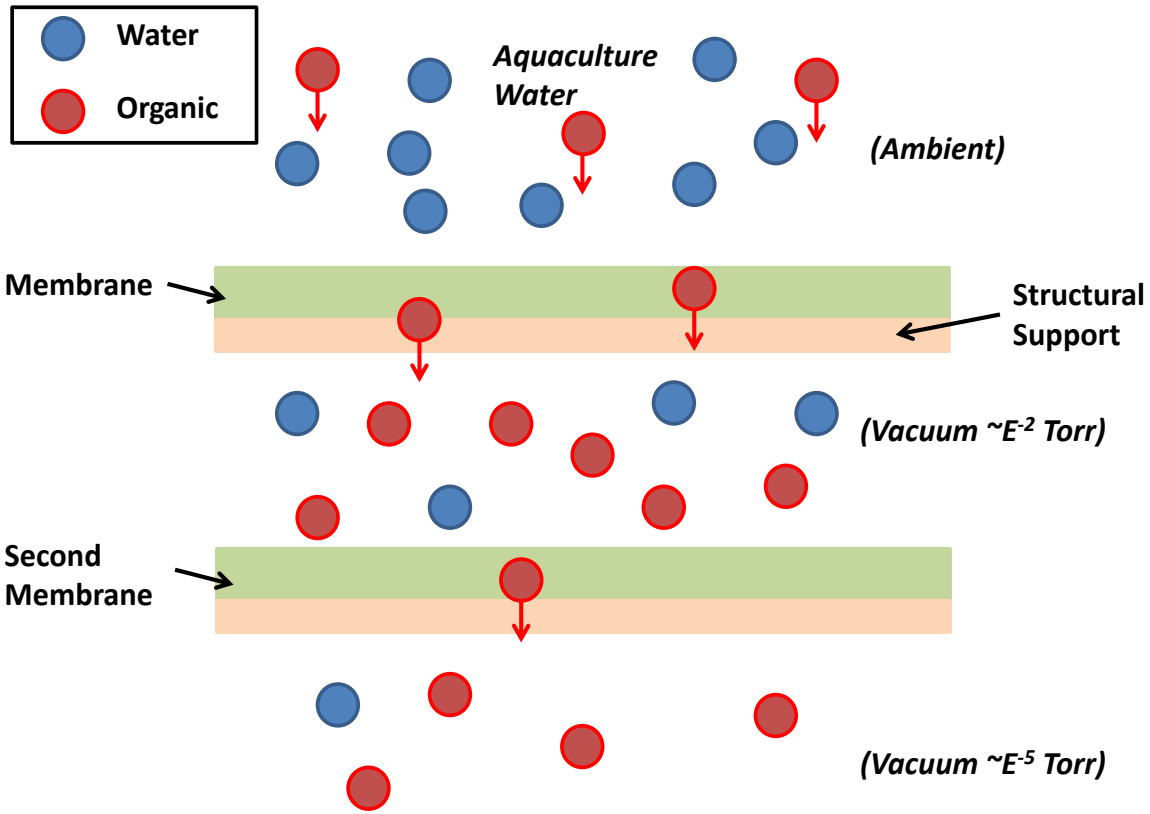


- **Sensitivity x10 across the mass range due to:**

✓ Improved coupling between ion source region and single filter QMS.

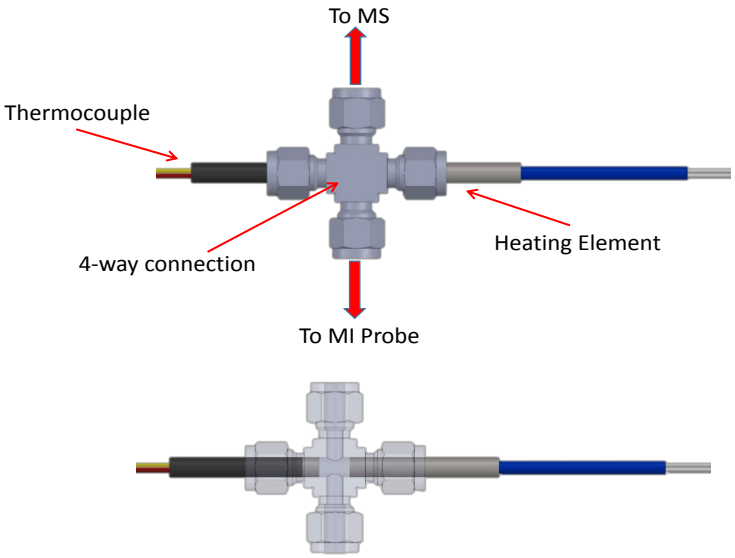
✓ Increased ionization efficiency due to increased electron path lengths in the source region.

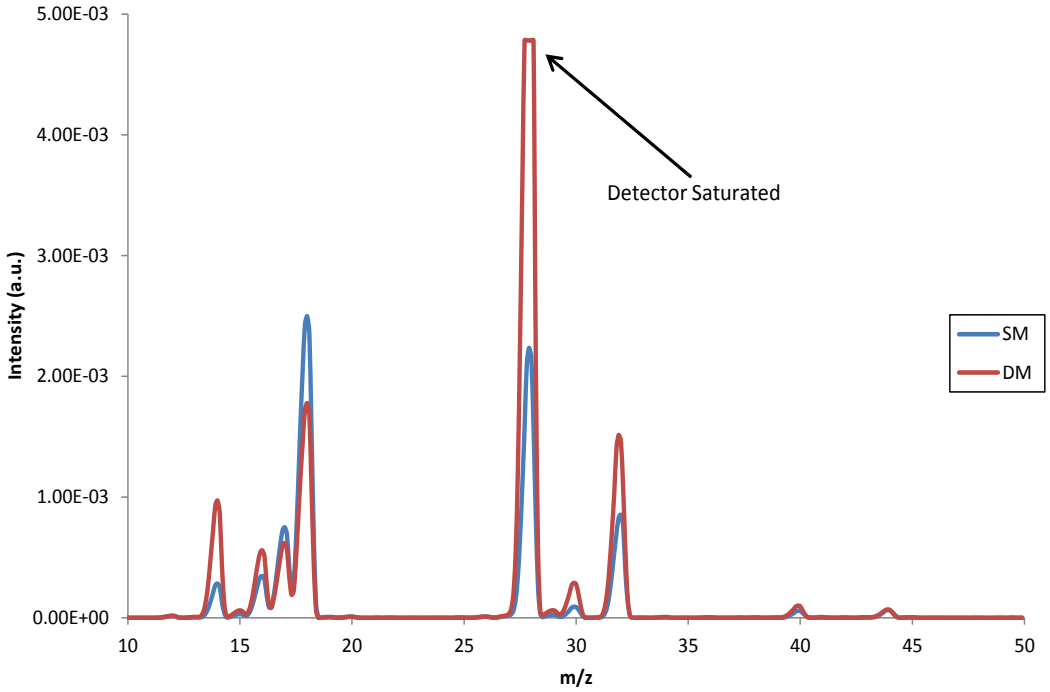
Membrane Inlet Mass Spectrometry



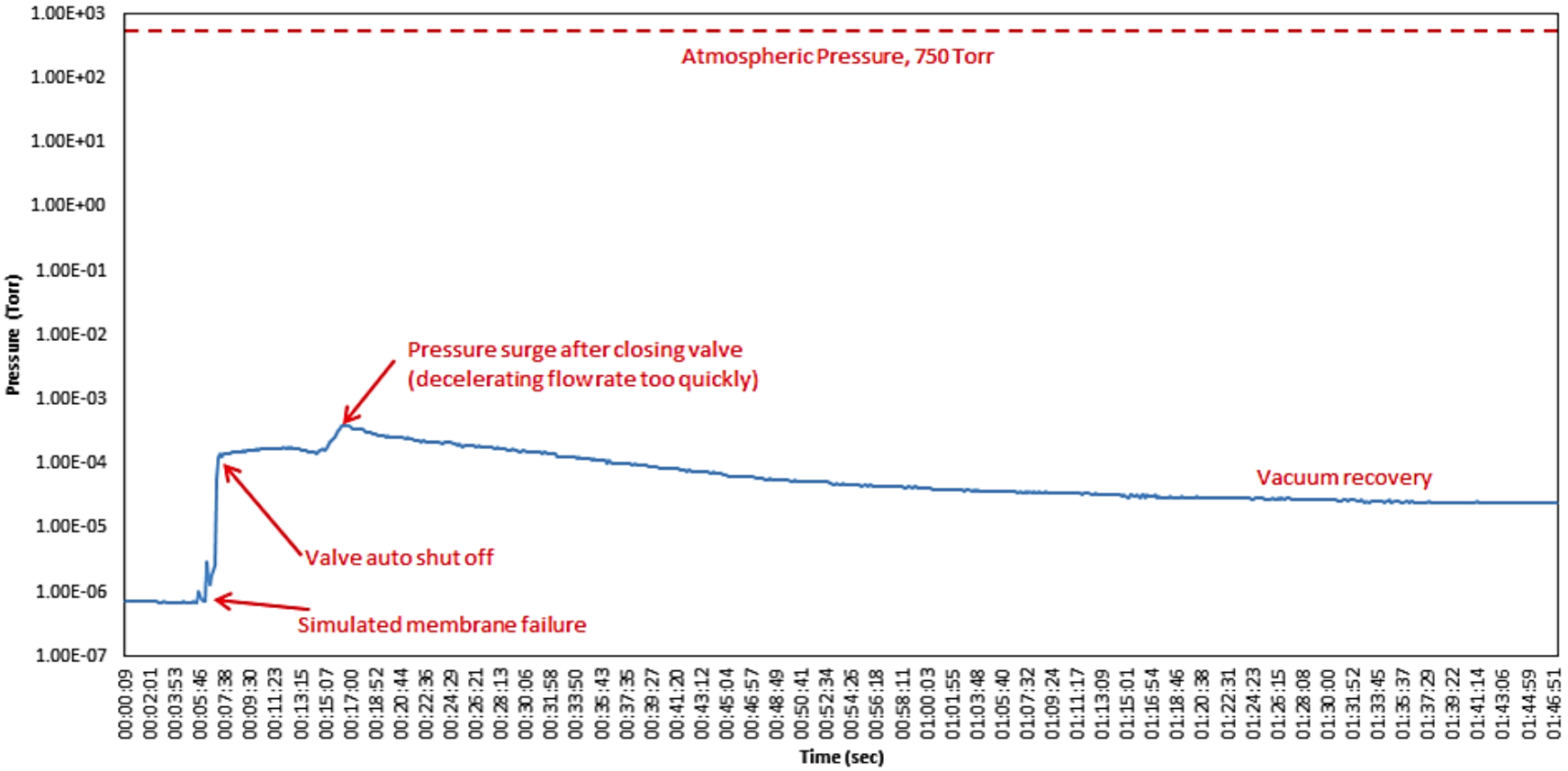
Double Membrane Inlet Process: Sample passes two concentration stages. Allows reduced water influx and increased signal to background levels.

Membrane Inlet Mass Spectrometry





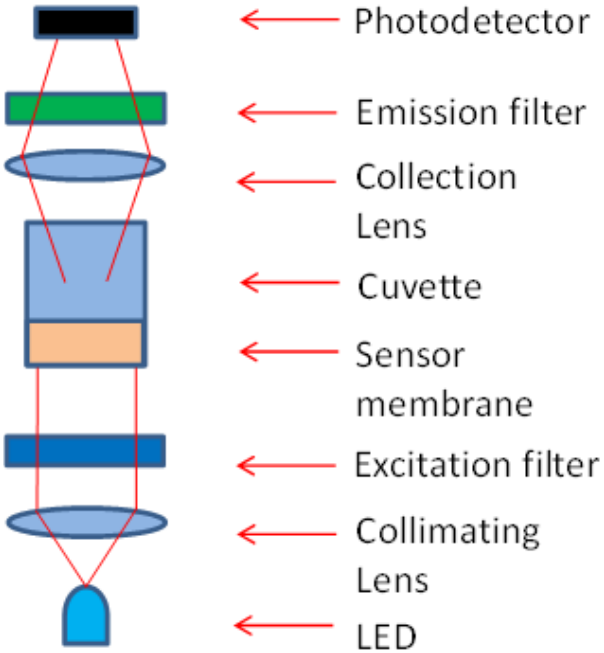
Membrane Inlet Mass Spectrometry



Fail-safe membrane protection system response to a catastrophic membrane failure

UV Sensor

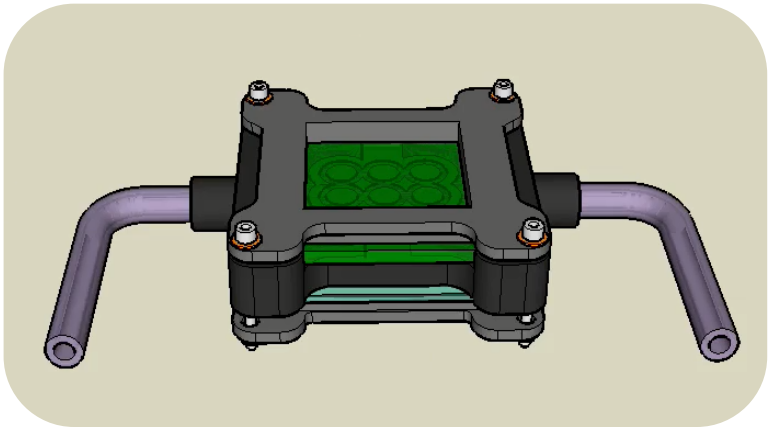
- There is significant contamination of water resources and an accelerating accumulation of heavy metals in the human food chain. These metals may enter aquatic systems by natural geochemical processes or anthropogenic sources include mining and other industrial processes..

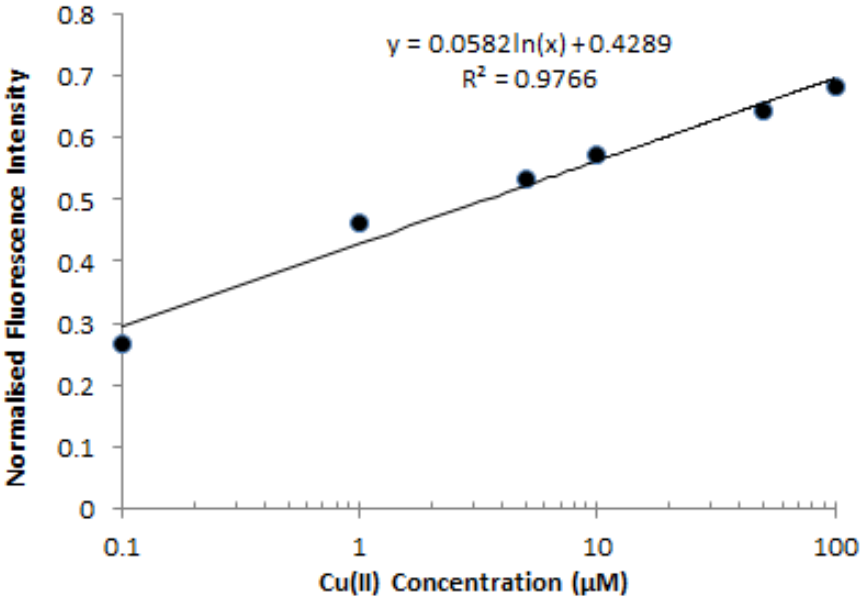


- The sensing mechanism is based on a metal ion sensitive membrane which consists of a polyurethane hydrogel embedded with a selective fluorophore.
- Upon complexing with a metal ion the fluorescence of the fluorophore is quenched by the metal ion allowing detection and quantification.

UV Sampling Cell

- A multi-sample fluidic sampling cell allows detection of multiple heavy metal ions in parallel.

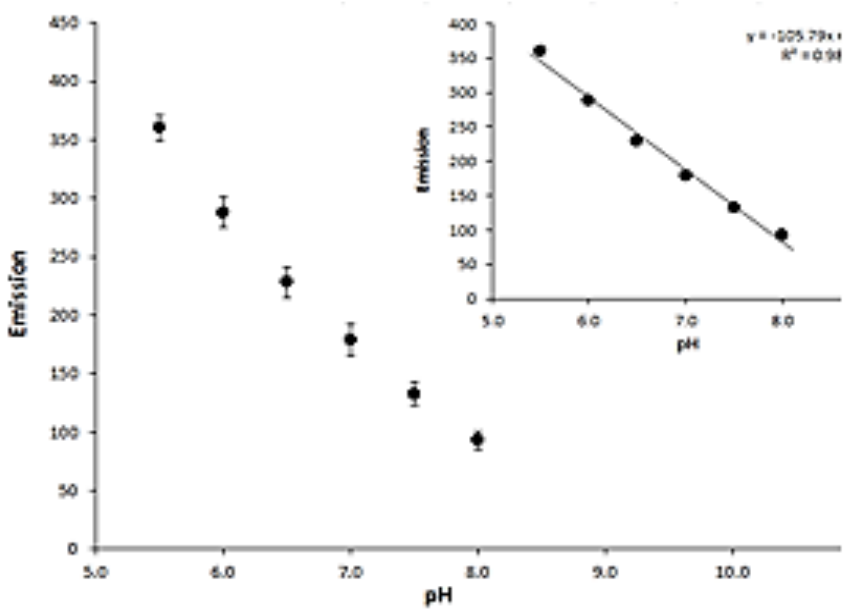


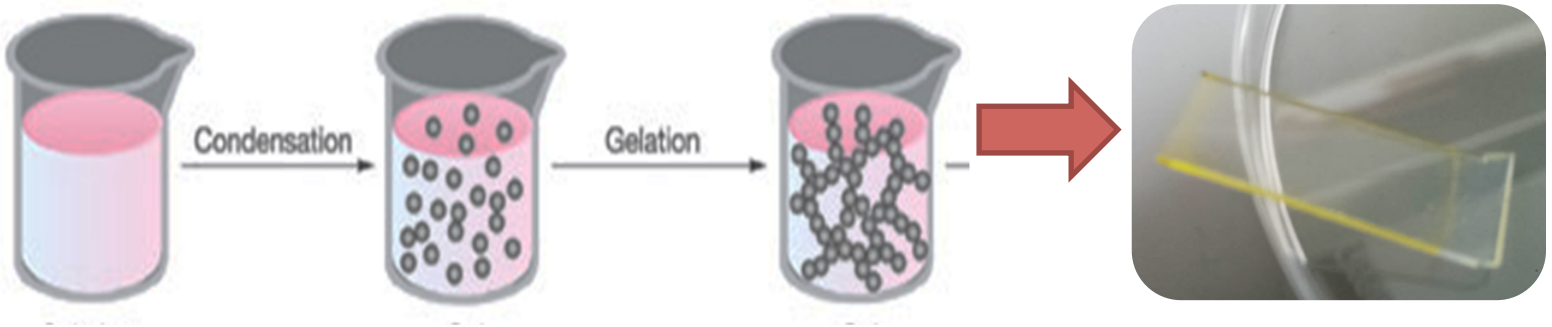


- Example calibration curve for Cu(II) at pH 7. Intensity data normalised to |(F-F0)/F0| where F0 is the fluorescence before adding the sample and F is the fluorescence after addition of ionic sample

Optical pH Sensing

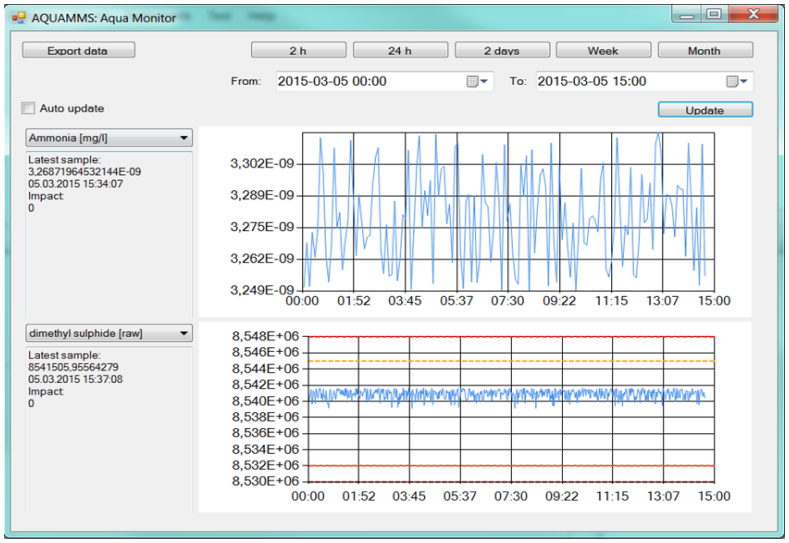
- Optical pH sensor developed using **a sol-gel process:** small, lightweight and EMI immune
- pH-sensitive dye is immobilized within the silica thin film deposited onto a glass slide through a dip-coating process.





Integration and Interface

- AquaMMS software designed to be used by **non-specialist** farm personnel.
- Alert is given in the event of a pollutant parameter being detected or rising above a set level during operation.



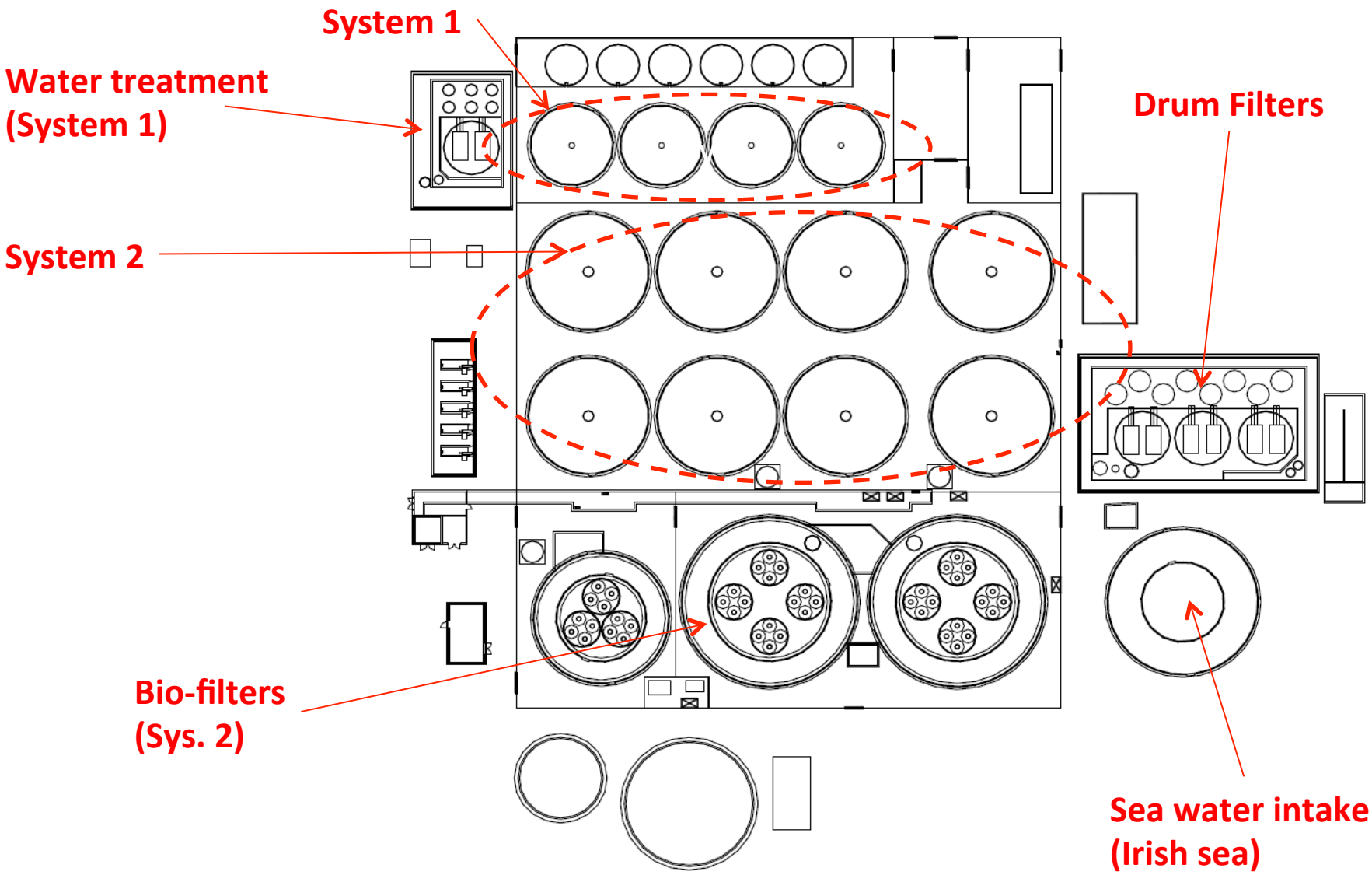
- System housed in water-tight marine grade SS.
- System draws ambient air through a Gore-Tex filter maintained at a slight positive pressure to minimize water ingress.
- System is backed by a UPS to provide an additional ~30 mins of electrical power.

On Site Testing at Anglesey Aquaculture

Anglesey Aquaculture (AAL) is the foremost supplier of fresh, sustainably farmed **sea bass** to the UK market and is currently the world's **largest,** commercial scale seawater Recirculating Aquaculture System

AAL produce about 1000 tonnes of sea bass per annum

On Site Testing at Anglesey Aquaculture

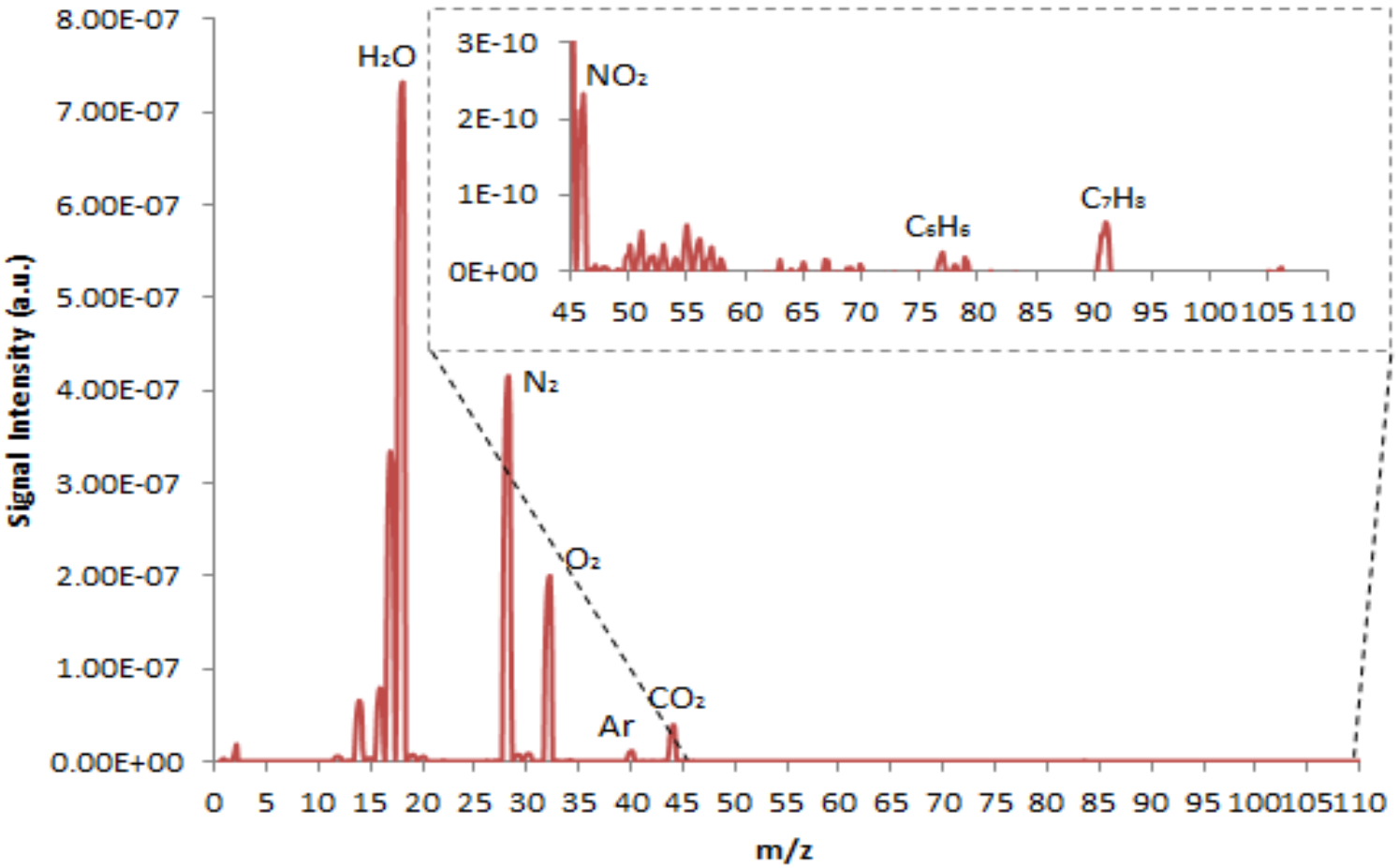


On Site Testing

Harsh Environment

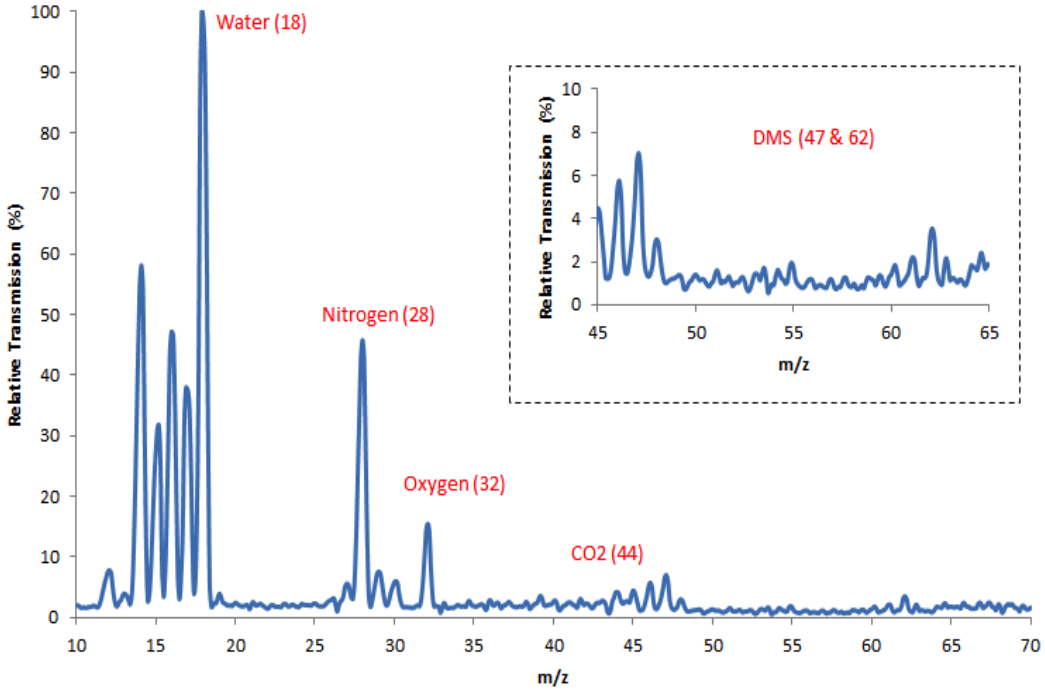
- Corrosive atmosphere (high salt content)
- High humidity
- Regular power outages
- Very warm (> 30°c)

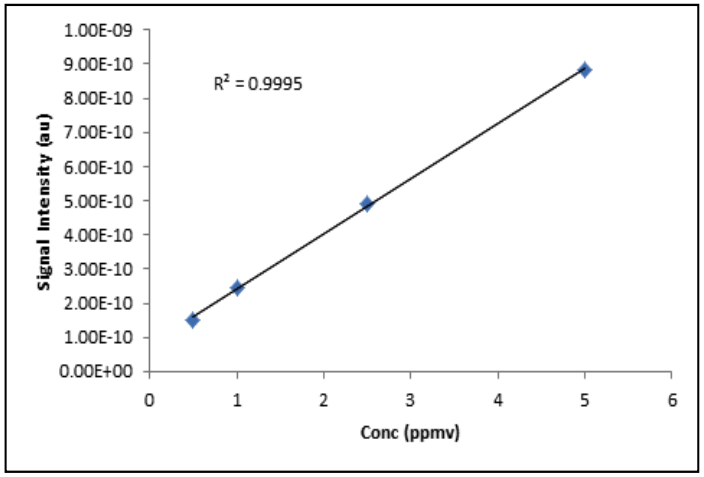
On Site Testing



Analytes measured above including trace BTXs – from nearby Irish sea shipping

On Site Testing

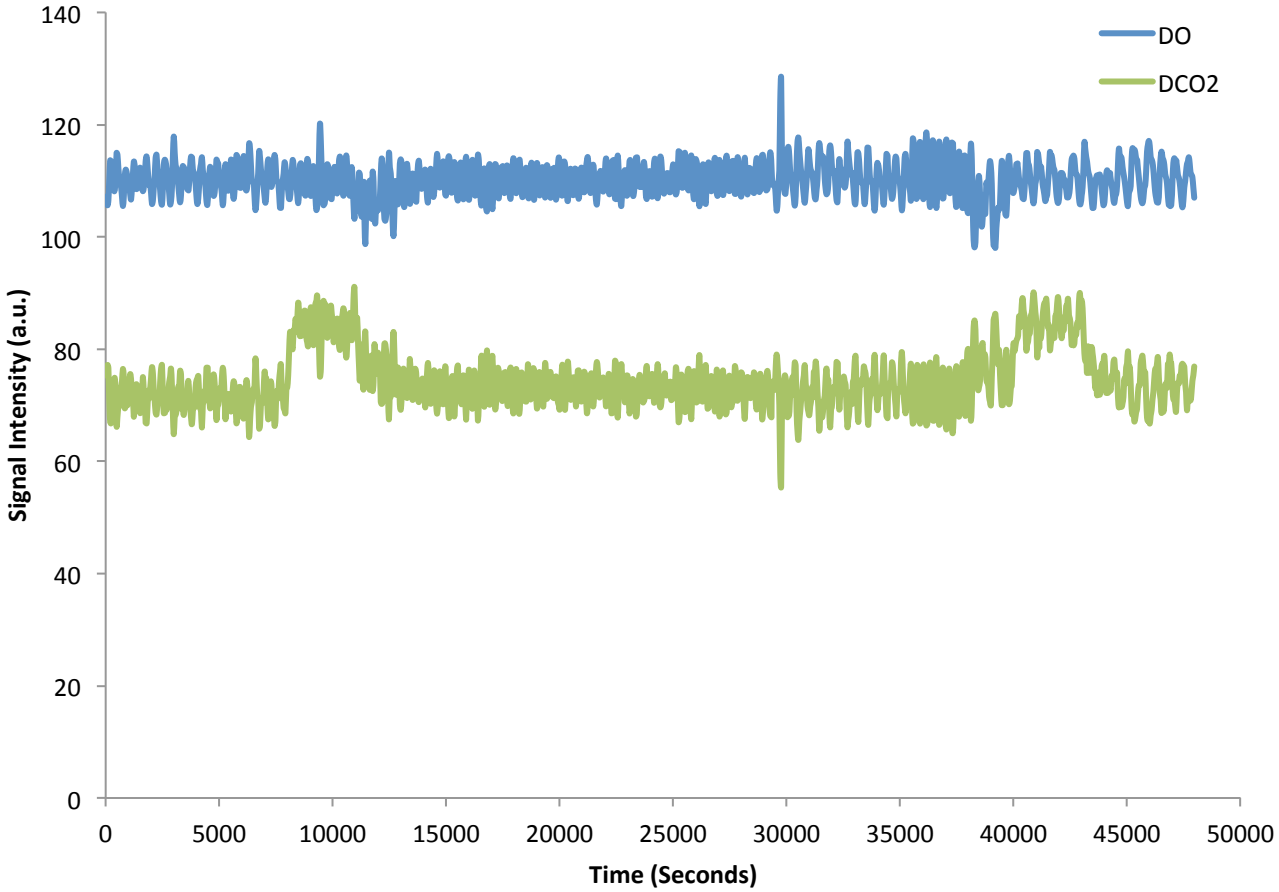




- Results allow measurement of respiration and de-nitrification rates, plus alarm for any high levels of toxins e.g. H_2S, DMS, geosmin etc

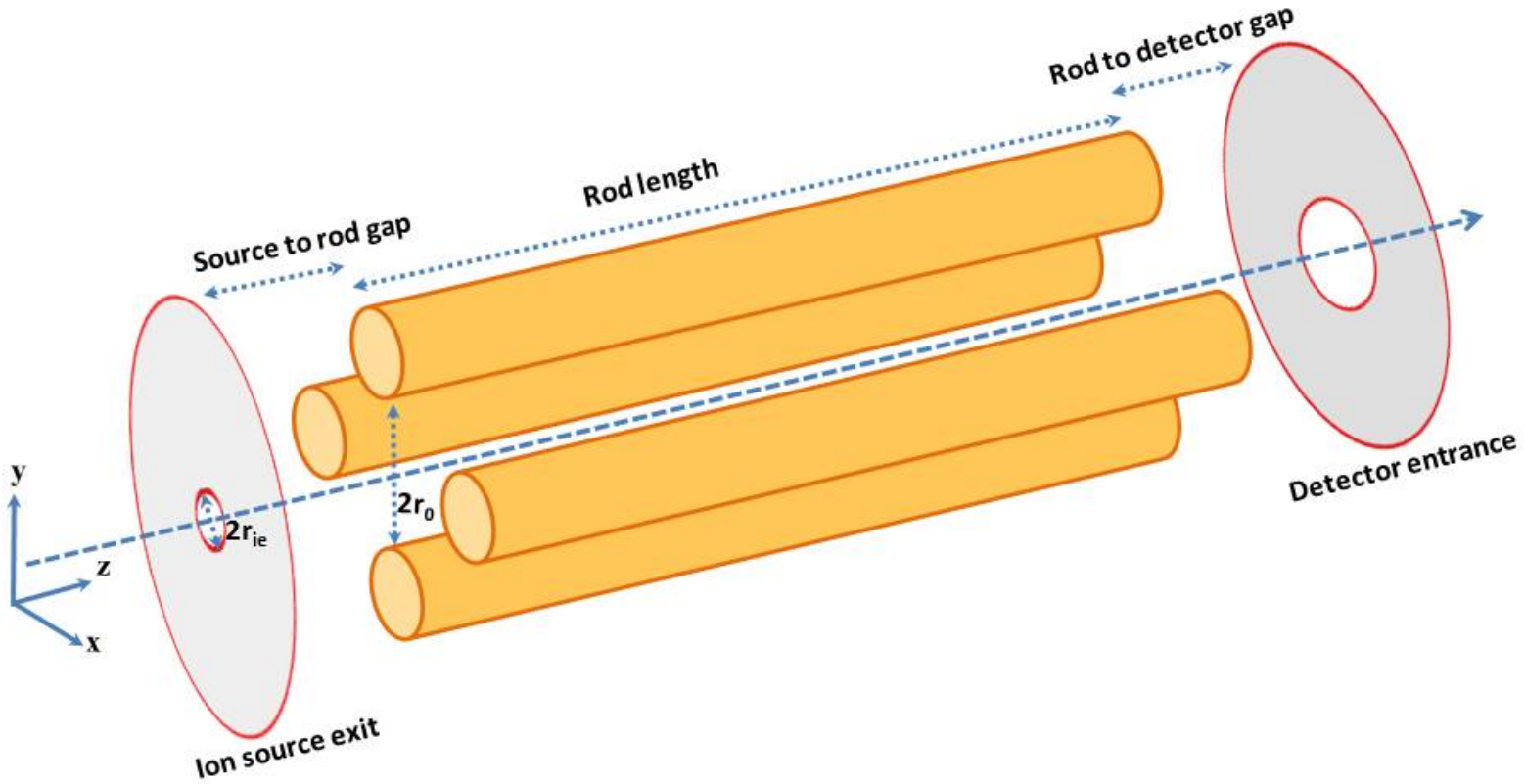
On Site Testing

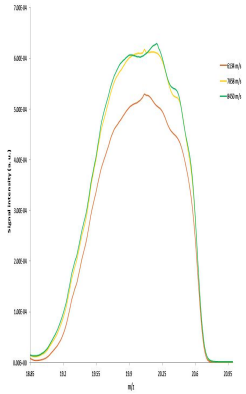
- Dissolved oxygen and carbon dioxide trends over ~13 hour period.



- CO_2 increases correlate with feeding times (increased activity and respiration)
- Oxygen level maintained via oxygen sensor / diffuser on control loop

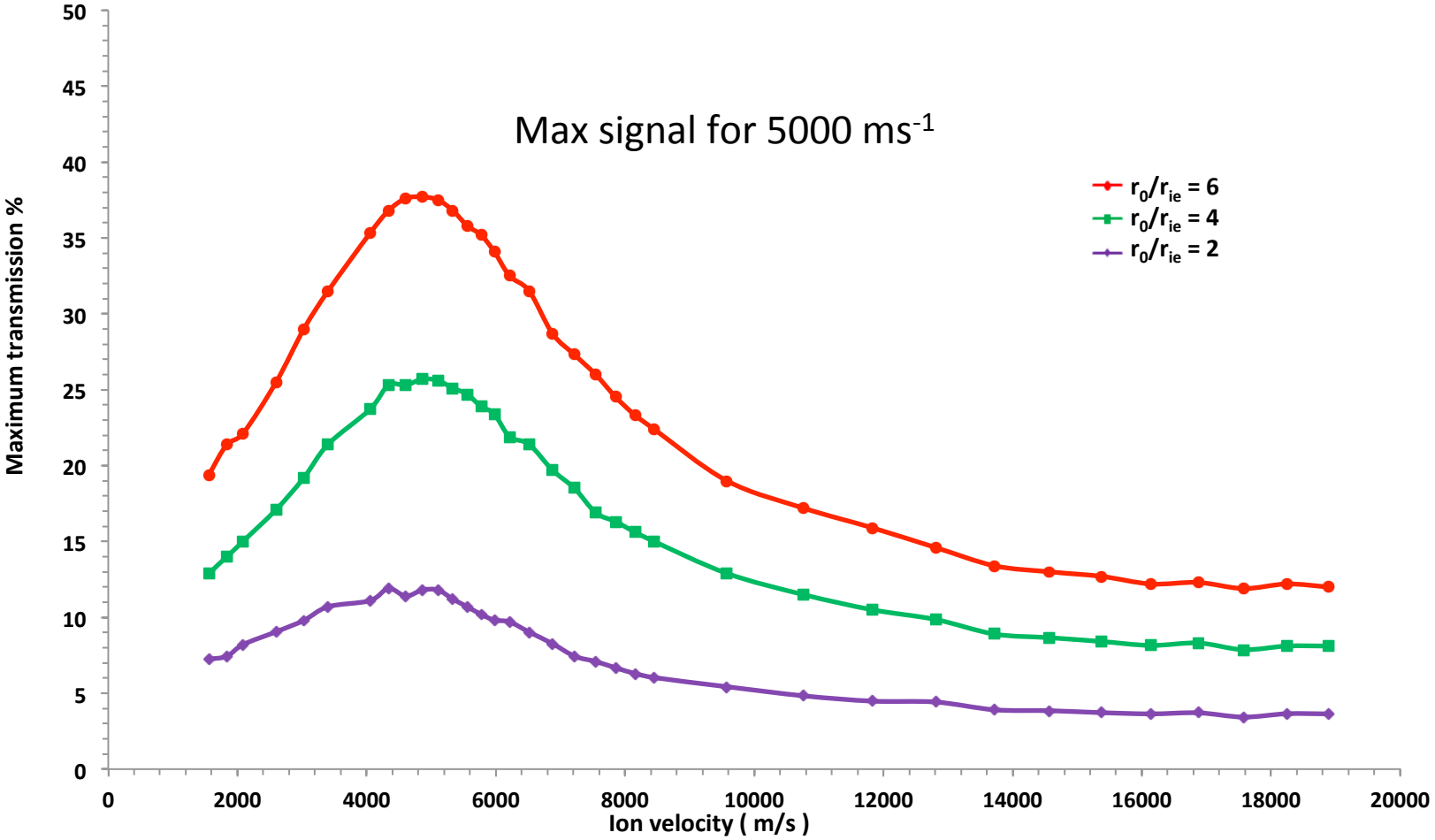
Future work: optimisation of ion source to QMF coupling





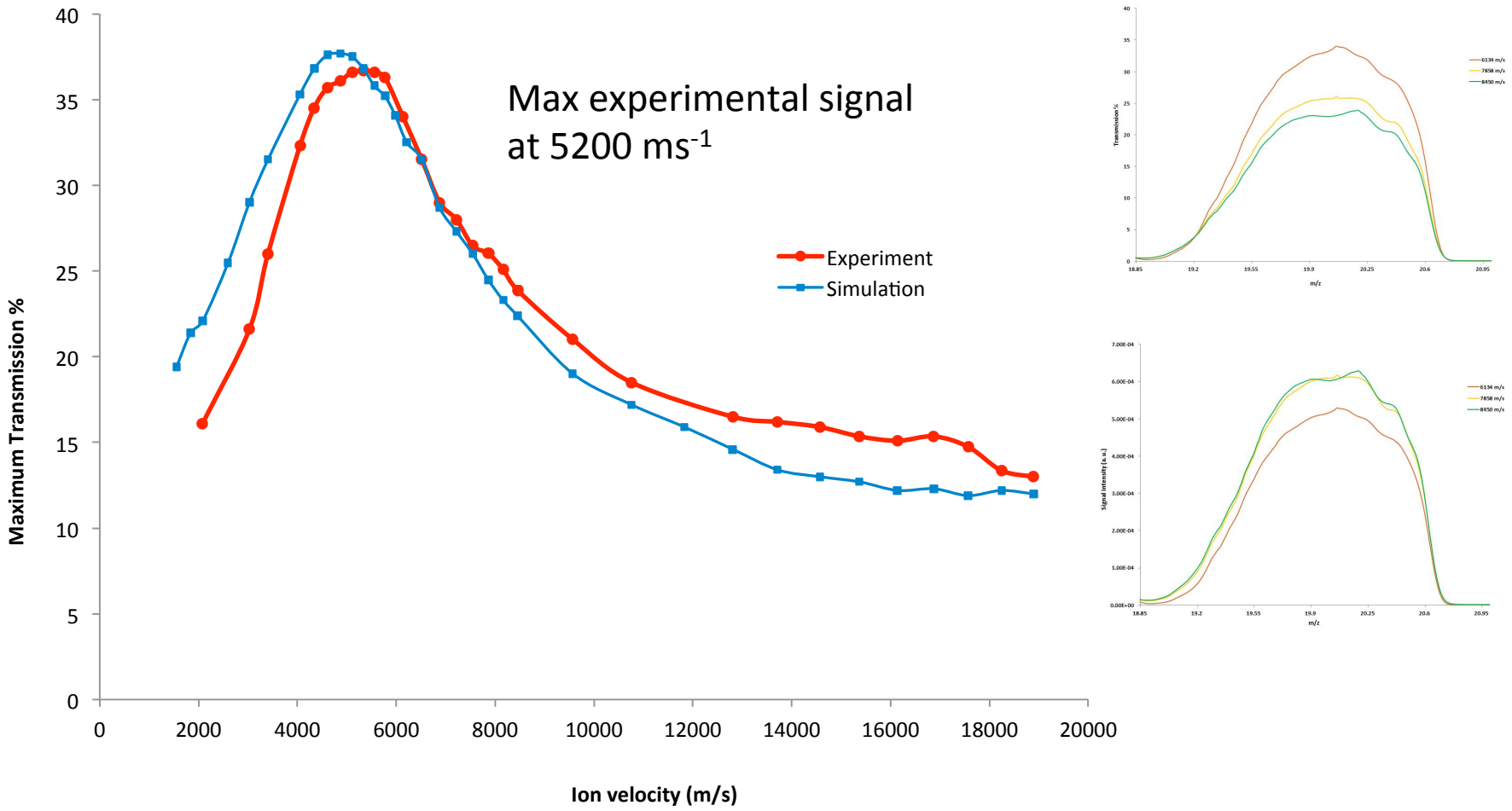
3D simulation: Field calculation by Boundary Element Method, mass spectra simulation by individual computation of >10^6 ion trajectories.

Future work: optimisation of ion source to QMF coupling



3D simulation: maximum % transmission versus ion velocity for different r_0/r_{ie} ratios. High coupling of ions into mass filter **without** prefilter

Future work: optimisation of ion source to QMF coupling



Experimental match to simulation: source gap 2mm, $^{20}Ne^{+}$,RF frequency 2 MHz. maximum % transmission versus ion velocity. Inset upper: exp, inset lower: theory

Conclusions

- **AquaMMS** is a novel sensor combining magnetically enhanced MS, UV fluorescence and optical pH as complementary techniques.
- Water quality has been monitored over limited time intervals at various locations in the water treatment cycle of a large RAS.
- Heated double membrane is allows trace detection of key analytes
- The instrument offers flexible, online monitoring of water quality at aquaculture farms, early warning of potentially harmful changes in water quality (toxins, pollutants etc) allowing the farmer time to make rapid management decisions to resolve the problem.
- Implementation of optimisation of ion source coupling to QMF is ongoing
- Extended field trials (Oct 2015) to take place in Telemarkroye, Norway

Acknowledgements

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