Technical University of Denmark

Report on Baltic Sea Region

Short Course in Salt Water Recirculation Aquaculture Technology 5th – 9th October 2013

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Publication date:
2014

Document Version
Publisher's PDF, also known as Version of record

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Baltic Sea Region
Programme 2007-2013

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

AQUABEST

AQUABEST

Finnish Game and Fisheries Research Institute, Helsinki
2014

ISBN 978-952-303-092-3

AQUABEST

Reports of Aquabest projects 17 / 2014

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Description

Authors		
Lars-Flemming Pedersen & Alfred Jokumsen		
Title		
Report on Baltic Sea Region Short Course in Salt Water Recirculation Aquaculture Technology 5th – 9th October 2013		
Year 2014	**Pages** 37	**ISBN** 978-952-303-092-3
Abstract		
The primary aim of the course was to transfer knowledge on recirculation aquaculture technology to fish farmers in the Baltic Sea Region. The course was targeted at consultants and representatives of core aquaculture organizations within the BSR countries, in order for them to subsequently disseminate the acquired knowledge to local fish farmers. The objectives of the course was to provide the participant the ability to: - Recognize central treatment components in salt water RAS - Identify suboptimal water quality (rearing conditions) and assess corresponding actions - Apply treatment components for solids removal and dissolved matter - Distinguish nitrification from denitrification and compare important factors influencing both processes - Describe effects of feed loading and feed composition.		
Keywords		
Recirculation Aquaculture Technology, RAS, water quality, nitrification, denitrification, solids removal, dissolved matter		
Publications internet address		
http://www.aquabestproject.eu/reports.aspx		
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Additional information		

Contents

1. Preface

Baltic Sea Region Short Course in Salt Water Recirculation Aquaculture Technology

As a specific task of AQUABEST project DTU Aqua conducted a training course on fish farming in land-based saltwater systems targeted consultants and practitioners from across the Baltic Sea Region.

The course description and the open invitation was distributed to national collaborators and broadcasted at http://www.aquabestproject.eu/

The course was held from 5th to 9th October 2013 at Section for Aquaculture, DTU Aqua in Hirtshals, Denmark. 22 specially-chosen consultants and practitioners (out of more than 50 applicants) from Estonia, Latvia, Lithuania, Belarus, Poland, Germany, Sweden and Finland met at DTU Aqua at the North Sea Science Park in Hirtshals, Northern Jutland to learn about sustainable fish production. The focus of the course was on Danish know-how related to farming in land-based saltwater plants which are environmentally friendly due to efficient waste water treatment and reuse of the water.

The aim of the course was to inspire and provide the participants with tools to apply Danish knowledge and technology in environmentally sustainable and cost-efficient aquaculture to developing fish production in the other Baltic countries.

This report contains the training programme, a summary of the teaching and training activities and an evaluation of the course based on returned questionnaires.Power point presentations were provided for the participants as handouts and PDF documents however not included in this report due to data protection and copyright issue. For further information, please contact the course leader Lars-Flemming Pedersen (lfp@aqua.dtu.dk) or the course coordinator Alfred Jokumsen (ajo@aqua.dtu.dk).

We acknowledge financial support from the European Union (European Regional and Development Fund and European Neighbourhood and Partnership Instrument) as well as great help from colleagues contributing to the smoothly running of the course.

Baltic Sea Region Short Course in

Salt Water Recirculation Aquaculture Technology

5th – 9th October, 2013
Technical University of Denmark
Section for Aquaculture, Hirtshals, Denmark.

Baltic Sea Region
Programme 2007-2013

Part-financed by the European Union (European Regional Development Fund and European Neighbourhood and Partnership Instrument)

DTU Aqua
National Institute of Aquatic Resources

2. Course Program

Baltic Sea Region Short Course in
Salt Water Recirculation Aquaculture Technology
5th – 9th October, 2013
Technical University of Denmark - Section for Aquaculture, Hirtshals.

Saturday, 5/10 2013 (Day 1)

Time	Plenum sessions	Keywords	Responsible
08.30-09:15	Welcome & intro-duction	Aim and scope, presentation	LFP/AJO
9:15-10:00	Status of RAS	Flow through systems vs. RAS; land based vs. sea cages	LFP
10:00-10:15		Coffee /Tea break	
10:15-11:15	RAS concepts, brief introduction	Input /output, solids removal, aeration, degassing, water quality, biofiltration and management	LFP
11:15-12:00	Group work/ Exercise	RAS challenges	LFP
12:00-13:00		Lunch/Skaga	
13:00-14:00	Water quality I	Chemical water quality Ammonia, nitrite, nitrate, pH, O2, CO2 alkalinity, salinity, COD, heavy metals	LFP
14:00-14:45	Group work	Log book, test kits, analysis and sensors	LFP
14:45-15:00		Coffee /Tea break	
15:00-16:00	Water quality II	Microbial water quality Control of pathogens	LFP
16:00 18:00 22:00	Departure to Skagen (Top of Denmark) Dinner in Skagen Arrival at Hotel Skaga		LFP/AJO

Sunday, 6/10 2013 (Day 2)

Time	Plenum sessions	Keywords	Responsible
09.00-10:00	Feed – input and composition	Feed composition, N, P and org. matter Solid and suspended waste	AJTD/PBP
10:00-10:15	Coffee /Tea break		
10:15-11:15	Feed mass balance	Feed loading Production contribution model	AJTD/PBP
11:15-12:00	Presentation of results/ group work	Production contribution model	AJTD/PBP
12:00-13:00		Lunch/Skaga	
13:00-14:00	Solids removal	Mechanical filtration, sludge cones, drumfilters, swirl separation, contact filters	PBP
14:00-14:45	Group work		PBP
14:45-15:00		Coffee /Tea break	
15:00-16:00	Micro particles	Micro particles, particle size distribution	PAFE
16:00-17:00	Group work/ experiment		PAFE
18:30		Dinner at Hotel Skaga	PBP/PAFE

Monday, 7/10 2013 (Day 3)

Time	Plenum sessions	Keywords	Responsible
08.30-09:15	Biofiltration	Biofilter types, biofilm, nitrification process, nitrifying bacteria	LFP
09:15-10:00	Exercise	Nitrification	LFP
10:00-10:15		Coffee /Tea break	
10:15-11:15	Nitrification	Factors affecting nitrification Biofilter kinetics	LFP
11:15-12:00	Exercise pres-entation of results	Ammonia and nitrite degradation	LFP
12:00-13:00		Lunch/Nordsøen	
13:00-13:45	Water treatment and biofiltration	Pathogen control and disinfectants	LFP
13:45-14:45	Microalgae in SW RAS	Toxic micro algae in RAS	SJS
14:45-15:00		Coffee /Tea break	
15:00-16:00	Aeration and degassing	Aeration, stripping, super saturation, TGP, gas bubble trauma, N2, CO2, O2.	PVSK
16:00-17:00	Aeration and degassing exer-cise		PVSK
18:30		Dinner at Hotel Skaga	LFP/PVSK

Tuesday, 8/10 2013 (Day 4)

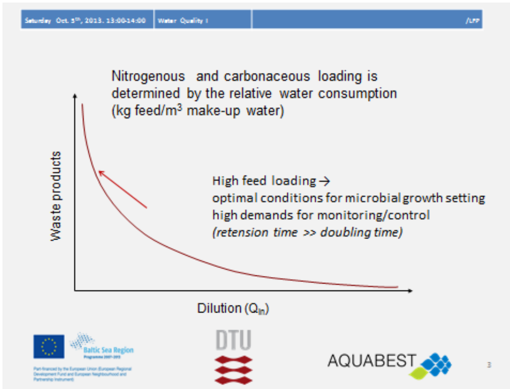
Time	Plenum sessions	Keywords	Responsible
08.30-09:15	Effluent treatment	How to deal with RAS effluent End of pipe, constructed wetlands Geo-bags	KSU/MVAH
09:15-10:00	Exercise/demonstration	Sludge separation, denitrification set-up	KSU
10:00-10:15	Coffee /Tea break		
10:15-11:15	Sludge handling denitrification	Hydrolysis, VFA, factors affecting denitrification	KSU/COLG
11:15-12:00	System design	End-of-pipe vs. inline; single sludge blanket	KSU/COLG
12:00-13:00	Lunch/Nordsøen		
13:00-14:00	Introduction to exercise Denitrification	Batch scale experiments; spiking, acetate, nitrite, nitrate, VFA.	KSU/COLG
14:00-14:45	Exercises	Batch scale experiments; spiking, acetate, nitrite, nitrate, VFA.	KSU/COLG
14:45-15:00	Coffee /Tea break		
15:00-16:00	Sludge handling Denitrification Exercises		KSU/COLG
16:00-17:00	Presentation and discussion of results		KSU/COLG
18:30	Dinner at Hotel Skaga		KSU/ COLG

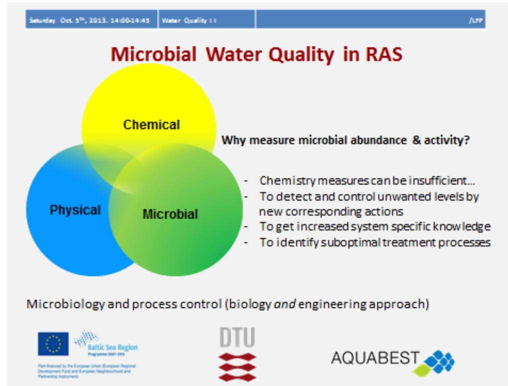
Wednesday, 9/10 2013 (Day 5)

Time	Plenum sessions	Responsible
09.00- 09:45	Course evaluation	LFP/AJO
10:00	Departure to Aalborg Congress & Culture Centre (incl. lunch)	
12:30 17:30	Attending Farmers Day Workshop	

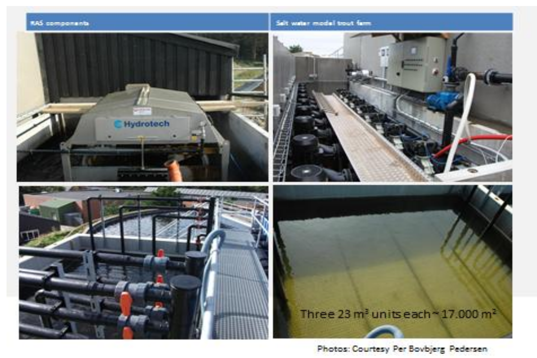
3. Farmers day

In the following link: http://www.aquacircle.org/farmersday2013 you will find the full programme of Farmers day along with pdf-files of all presentations.


Nitrogenous and carbonaceous loading is determined by the relative water consumption (kg feed/m³ make-up water)
Waste products
High feed loading →
optimal conditions for microbial growth setting
high demands for monitoring/control
(retension time >> doubling time)
Dilution (Q_{in})
DTU
AQUABEST


Microbial Water Quality in RAS
Chemical
Physical
Microbial
Why measure microbial abundance & activity?
- Chemistry measures can be insufficient…
- To detect and control unwanted levels by new corresponding actions
- To get increased system specific knowledge
- To identify suboptimal treatment processes
Microbiology and process control (biology and engineering approach)
DTU
AQUABEST


DTU
AQUABEST


Hydrotech
Three 23 m³ units each ~ 17.000 m²
Photos: Courtesy Per Bovbjerg Pedersen

Farmers' Day: Aquaculture workshop at Aalborg Congress & Culture Centre, Aalborg, Denmark.

Programme **Farmers Day - DanAqua in Aalborg 2013 - Wednesday, October 9th**

From	To	Min.	Subjects	Speaker
12:30	12:40	10	Welcome & Introduction by the Chair	Jacob Bregnballe, Chairman AquaCircle
12:40	12:50	10	The Danish Aquaculture Strategy	Mikkel Stage, The Danish AgriFish Agency
12:50	13:10	20	Use of RAS in Denmark – 10 years of experience	Brian Thomsen, Director, Danish Aquaculture Organisation
13:10	13:30	20	Switch-over from flow-through to RAS in Chile	Claudio G-H Puelma, Gerente de serv. y proyectos Recirc. Ltda.
13:30	13:50	20	Land based salmon farming in RAS - Danish Salmon	Mark Russell, Danish Salmon
13:50	14:10	20	Energy efficiency in RAS & Pump solutions for saltwater RAS	Mikael Zacho Jensen, Grundfos
14:10	14:30	20	UV water disinfection in RAS	Mathias Kristensen, UltraAqua
14:30	14:50	20	Oxygen / CO2 control in RAS	Paw Petersen, Oxyguard International
14:50	15:20	30	Coffee break	
15:20	15:40	20	Feed for recirculating aquaculture systems	Kim Schøn Ekmann, BioMar
15:40	16:00	20	Solids removal and effluent treatment	Henrik Mortensen, CM Aqua
16:00	16:20	20	Mortality handling and the containerized RAS	Gonzalo Boehmwald, AKVA group Chile
16:20	16:40	20	Perspectives in RAS smolt farming	Frode Mathiesen, Grieg Seafood
16:40	17:00	20	Application of vacuum airlift skimmers in RAS	Bertrand Barrut, COLDEP, France
17:00	17:20	20	Examples of and experiences with saltwater RAS	Bjarne Hald Olsen, Billund Aquaculture Service
17:20	17:30	10	Questions, answers, conclusions and closing the day	Jacob Bregnballe, Chairman AquaCircle

Wednesday, October 9th, 2013 from 12:30 – 17:30
Aalborg Congress & Culture Centre, Europa Plads 4, 9000 Aalborg
Please note registration is not required; additional info at www.DanAqua.net.

Arranged by

Dansk Akvakultur | AquaCircle | DTU Aqua National Institute of Aquatic Resources

Ministeriet for Fødevarer, Landbrug og Fiskeri | Den Europæiske Fiskerifond

4. List of participants

1. Alyssa Joyce, Tjärnö Marine Biological laboratory. **Sweden**
2. Marcis Zingis Inst. Food Safety, Anim. Health & Env., BIOR. **Latvia**
3. Armands Roze, ''FAPS''Ltd. **Latvia**
4. Otso Järvisalo, Ribtech OY, LAUKAA. **Finland**
5. Ola Öberg, Svensk Fiskodling, Järfälla. **Sweden**
6. Carsten Dietz, University of Kiel. **Germany**
7. Heiki Jaanuska, Inst. Vet. Med. and Animal Sci., Dep. of Aquaculture. **Estonia**
8. Tapio Kiuru, Laukaa. **Finland**
9. Mikael Björk, Svenskfiskodling, Järfälla. **Sweden**
10. Pasi Korvonen, Livia college, Kirjala. **Finland**
11. Stefan Askbrant, BIODYNAMIX, Västervik. **Sweden**
12. Mirosław Półgęsek, West Pomeranian Uni., Dep. Aquaculture, Szczecin. **Poland**
13. Lars Lönnström, Ålands Fiskförädling AB, Pargas. **Finland**
14. GZYL Mateusz, INSKO. **Poland**
15. Martti Naukkarinen, Lkalavesi, Sääskjärvi. **Finland**
16. Andre Pechura, Ratz - Aqua & Polymer Technik, Ramscheid. **Germany**
17. Nikolai Balurin, Belarusian State Agricultural Academy, Gorki. **Belarus**
18. Tatiana Liakhnovitch, Belarusian State Agricultural Academy, Gorki. **Belarus**
19. Aliaksandr Niakrylau, Belarusian State Agricultural Academy, Gorki. **Belarus**
20. Gunilla Jonsson, Svenskfiskodling, Järfälla. **Sweden**
21. Darius Nienius, Ministry of Agriculture of the Republic of Lithuania. **Lithuania**
22. Marcin Juchniewicz, Nowa Wieś Lęborska. **Poland**

5. Teaching and training staff

Name	Position	
Alfred Jokumsen	Senior advisory scientist	
Anne Johanne Tang Dalsgaard	Senior research scientist	
Carlos Octavio Letelier Gordo	PhD student	
Karin Isabel Suhr	Research scientist	
Lars-Flemming Pedersen	Senior research scientist	
Mathis von Ahnen	PhD student	
Paulo Fernandes	PhD student	
Per Bovbjerg Pedersen	Head of section	
Peter Vilhelm Skov	Associate Professor	

Svend Jørgen Steenfeldt

Research scientist

6. Summary of course sessions (Day 1- 4)

6.1. Session 1A. Introduction to Recirculation Aquaculture Systems and RAS units

The session included a presentation of the course and the recent transition towards RAS as well as a presentation of RAS components. The session included small a sight-seeing to the nearby research facility at DTU Aqua with focus on the 2200 m^3 land-based saltwater RAS.

The first lecture introduced different types of fresh- and saltwater aquaculture systems, and discussed the recent trend from open net-pens and flow-through systems (FTS) to RAS from an environmental and economic sustainable perspective. The major advantages and drawbacks of RAS were listed and discussed. Focus on relative water consumption was given, distinguishing between FTS with approx. 30-50 m^3 water/kg feed and intensive RAS down to 0.5 m^3 water/kg feed. Issues regarding consumers' perception of aquaculture in general and open net-pens in particular were stressed and current projects and progress towards land-based closed containment RAS was updated. The key message of the lecture was that *RAS is the future* and that sustainable development (environmental neutral expansion) of the sector needs to take profitability into account. Much is possible but not necessary economical feasible.

In the second lecture, different RAS components were introduced and discussed. In broad terms mechanical and biological filtration were explained and devices for aeration, degassing, circulation and disinfection were presented. Solutions and experience with solids removal and filtration were discussed before the Danish concept of the so-called Model Trout Farm (MTF) was presented. The background and current status of MTF was explained, and issues such as N, P and C removal, effluent treatment, escapees, improved fauna passages, legislation and monitoring was presented. Constructed wetland, sludge thickening methods and use of geobags® were mentioned and country specific issues were discussed.

The purpose of the experimental land based saltwater RAS at DTU Aqua and the experiences achieved so far were explained to the participants. The excursion included presentation of the fish tank, the inline treatment units (drum filter, biofilter and trickling filter) and the end of pipe treatment compartments (hydrolysis tank, denitrification units and a constructed wetland).

Expected learning objectives:

- Identify challenges associated with flow-through (FTS) and RAS
- Give examples on the Danish Model Trout Farm (MTF) concept
- Explain purpose of different RAS treatment units.

Supplementary hands-out literature for session 1A:

1. Martins, C. I. M., Eding, E. H., Verdegem, M. C. J., Heinsbroek, L. T. N., Schneider, O., Blancheton, J. Roque dÒrbcastel, E. & Verreth, J. A. J. (2010). New developments in recirculating

aquaculture systems in Europe: A perspective on environmental sustainability. *Aquacultural Engineering*, *43*(3), 83-93.
2. Dalsgaard, J., Lund, I., Thorarinsdottir, R., Drengstig, A., Arvonen, K., & Pedersen, P. B. (2013). Farming different species in RAS in Nordic countries: Current status and future perspectives. *Aquacultural Engineering, Vol. 53:2-13*.

6.2. Session 1B. Water quality in RAS

The session included presentations of I. Chemical water quality, and II. Microbial water quality. At the end of the session, country specific information on aquaculture status was disseminated based on questionnaires received prior to attending the course.

The first lecture defined water quality as a matrix of chemical, physical and microbial factors under the influences of biotic and abiotic conditions. Effects of feed loading, aeration, biofiltration, particle removal, disinfection etc. were shown and main chemical water quality parameters were presented. Accumulation of certain waste products in RAS was stressed, and free ammonia toxicity, ammonia/ammonium equilibrium and pH dependence, nitrite, nitrate, alkalinity, oxygen, carbon dioxide, organic matter was described. Emphasis on test kits and proper measurements (N-based concentration, equivalent concentrations, molar concentrations and units in e.g. mg/l, g/m^3 or ppm were calculated from examples).

In the second lecture focus was given on the concept of microbial water quality; the presence and activity of heterotrophic bacteria, fungus, protozoan including parasites and micro algae.

Due to increased retention time in RAS and constant C, N and P loading, conditions for heterotrophic growth are close to being optimal. The importance of rapid and efficient solids removal was discussed, as was measures to detect and corresponding actions to control microorganisms. Different methods to assess microbial abundances were compared and examples of water treatment using chemical agents were given.

Expected learning objectives:

- Identify important chemical water quality parameters
- Assessment and calculation of TAN, NO_2^- and NO_3^- concentrations in water samples
- Explain importance of microbial control in RAS

Supplementary hands-out literature:

1. Noble, A. C., & Summerfelt, S. T. (1996). Diseases encountered in rainbow trout cultured in recirculating systems. Annual Review of Fish Diseases, 6, 65-92.
2. Colt, J. 2006. Water quality requirements for reuse systems. Aquacultural Eng. 34, pp. 143–156.
3. Country specific questionnaires from Germany, Finland, Belarus, Poland, Estonia and Sweden.

6.3. Session 2A. Feed input and waste composition and form

The session consisted of a Power Point lecture alternating with minor exercises. A general introduction to aquaculture waste was given, summarizing the origin (ultimately the feed), nutrient composition (primarily nitrogen, phosphorous and organic matter), and different waste forms (particulate and dissolved), which are removed in RAS using different cleaning technologies.

Examples on how to quantify / calculate the different waste forms were subsequently given on the black board followed by exercises. Hence, the participants should by the end of the session be able to calculate the amount of solid and dissolved waste nitrogen, phosphorous and organic matter originating from a certain amount of feed allocated to the fish prior to cleaning.

DTU Aqua has set up an Excel-based Waste Model that can carry out these calculations based on certain input information. The model is used by Danish authorities and was distributed to the participants in the second half of the session for them to get acquainted with.

Learning objectives:

- Describe the origin and major nutrient composition of aquaculture waste
- Explain importance of different waste forms
- Calculate solid and dissolved inorganic nutrient waste fractions
- Calculate organic matter waste

Supplementary hands-out literature:

1. D.P. Bureau and Hue, K. 2010. Review article. Towards effective nutritional management of waste outputs in aquaculture, with particular reference to salmon aquaculture operations. Aquaculture Research, 41, 777-792.
2. Dalsgaard, J, and Pedersen, P.B. 2011. Solid and suspended/dissolved waste (N, P, O) from rainbow trout (*Oncorynchus mykiss*). Aquaculture, 313, 92-99.

6.4. Session 2B. Solids removal and mechanical filtration

The session consisted of two Power Point lectures alternating with minor exercises. A general introduction to particles, their origin and importance was given. Methods to remove particles (solids and suspended waste) was presented e.g. sedimentation ponds, sludge cones and swirl cones, as well as belt, drum and contact filters. Theory on micro particle generation and removal was presented, exemplified with foam fractionators and explained with removal in constructed wetlands based on data from commercial fish farm. The composition of particulate matters was illustrated and aerobic and anaerobic degradation was described.

In the other lecture, micro particle was introduced and put into RAS perspective. The potential consequences of micro particles on biofilter nitrification (ammonium and nitrite removal) and fish performance (gill issues) were given. Focus on organic matter content, suspended solids and methods to estimate particle abundance and distributions were made, and examples on heterotrophic competition causing reduced nitrification was explained. Recent examples on micro particle steady state in RAS were explained, and relations between particle size, numbers and distribution, surface and volume was described.

Learning objectives:

- To understand the origin of solids and the importance of removing them from RAS
- Explain different methods to remove solids

6.5. Session 3A. Biofilter performance and nitrification

The session consisted of two Power Point presentations (I. Biofilters and II. Factors affecting nitrification) including minor exercises.

The first lecture introduced concepts of biofiltration, organic matter and nitrogenous removal and the nitrification processes. The three rate limiting factors – TAN substrate, oxygen and alkalinity were mentioned and examples of TAN and nitrite removal rates were given. Various types of biofilters were illustrated and start-up processes in biofilters were described. Fixed bed vs. moving bed filters and biofloc systems were compared and measures to evaluate biofilter performance was presented.

In the second lecture, examples on ammonia and nitrite removal rates were shown and a number of examples on factors affecting nitrification kinetics were given. Abiotic factors were exemplified by graphs, figures and flip board and included factors like turbulence, pH, alkalinity, oxygen, organic matter, substrate concentration, temperature, salinity. For each parameter examples with relevant data were given and discussion with the participants including empirical experience and observations. Particular focus was directed on ammonia and nitrite limited removal capacity (0 and 1st order kinetics), alkalinity control and pH/oxygen content in the water phase compared to inside the biofilm and the importance of physics on biofilter performance (hydraulic film diffusion and uneven hydraulic distribution). Topics like change in feed loading, consequences of back washing and use of disinfectants were presented and issues regarding robustness were stressed. The presentations covered various aquaculture related aspects and were practically oriented by including valuable comments from the audience.

Expected learning objectives:

- Identify and prioritize important factors affecting nitrification
- Compare different types of biofilters and interpret measures of biofilter performance.

Supplementary hands-out literature:

1. Chen, S., Ling, J., & Blancheton, J. P. (2006). Nitrification kinetics of biofilm as affected by water quality factors. *Aquacultural Engineering*, *34*(3), 179-197.
2. Pedersen, L. F., Suhr, K. I., Dalsgaard, J., Pedersen, P. B., & Arvin, E. (2012). Effects of feed loading on nitrogen balances and fish performance in replicated recirculating aquaculture systems. *Aquaculture*, *338*, 237-245.

6.6. Session 3B. Water treatment; toxic algae blooms and gasses, aeration and degassing

The session covered three topics:

I. Water treatment

II. Toxic micro algae

III. Gasses, aeration and degassing.

I. Water treatment

Water treatment in salt water RAS was briefly presented. Needs and challenges associated with application of disinfectants in RAS were presented. The concept of treatment window (ensuring treatment efficacy and the same time ensuring no adverse effects on fish, personal, nitrifyers or receiving water body) was defined and examples on treatment regimens were introduced.

Expected learning objectives:

- Describe options and challenges of water treatment in RAS

II. Toxic microalgae

The second lecture reviewed toxic algae and harmful algal blooms (HAB). The presentations included introduction to harmful algae, global impact, distributions, effects and mode of action, monitoring methodology and actions to avoid HABs. The presentation included two cases of HABs related to RAS, one in freshwater and one in a brackish water RAS.

Expected learning objectives:

- To recognize algae as potential harmful micro-organisms
- Explain risks of toxic micro algae in RAS

III. Gases, aeration and degassing

The third lecture introduced the participants to the fundamentals of dissolved gases, solubility of gases in water, partial and total gas pressures in water, problems associated with supersaturating with gases, and methods for aeration and degassing. The session was concluded with an exercise.

Fundamentals of dissolved gases covered the gas species in atmospheric air, their volume and mass percentage contributions, the specific mass of different gases. Correction factors to be applied when calculating partial pressures at elevation due to changes in barometric pressure were covered, as were calculations of water vapour pressures at different temperatures. Conversions between partial pressures and content were exemplified.

Attendees learned to calculate solubility of different gases under conditions of changing temperature and salinities using known constants, mole fractions of different gas species, and from Bunsen coefficients that they were to calculate. The purpose was to enable participants to calculate solubility of gases under different environmental conditions and to demonstrate how solubilities of gases decline with increasing temperature and salinity.

The lecture also touched on the difficulties associated with measuring solubility of CO_2 in water due to carbonate chemistry, and the hydration and dehydration of carbon dioxide under temperature and pH conditions.

Aspects of total gas pressures were emphasized in the lecture, due to the significant risk of gas supersaturation in systems that utilize pure oxygen rather than traditional aerators and degassers. Attendees discussed sources of supersaturated water and the risk of build-up of other gas species in different types of systems.

The physical laws that govern gas transfer between air and liquid were covered; gas transfer coefficients, surface area for exchange, and the driving forces of concentration gradients. These were exemplified in different devices used for aeration and degassing, and were further used to calculate efficiencies of different devices and comparing operational costs of running devices in a facility.

The lecture was concluded with an exercise where attendees were to calculate transfer rates, and efficiencies based on a data set obtained from an aerator running in freshwater and seawater.

Expected learning objectives:

- to calculate solubility of different gases under various conditions
- to be introduced to causes and consequences of super saturation in RAS

6.7. Session 4A. Introduction to effluent treatment in RAS

This first session on effluent treatment opened with a lecture part and ended with a practical lab work part.

The lecture had two Power Point presentations; I. Introduction to effluent treatment and II. Constructed wetlands. The first was a general introduction to effluent treatment and addressed how to deal with RAS effluent; dissolved and solid matter effluents, N, P, COD, and environmental legislation aspects. The latter included a discussion on legislation in the different Baltic Sea Region countries as the participants had filled in a questionnaire on this topic before attending the course.

The second lecture focused on constructed wetlands and covered the advantages and disadvantages of such systems; the different kinds of wetlands, construction, dynamics of nutrient transformation, lifespan and efficiency.

The laboratory exercise was performed in groups of 4 persons at the facilities of DTU Aqua, North Sea Science Park in Hirtshals. In the exercises, the participants had to measure the denitrification rates of hydrolyzed sludge at different environmental conditions.

Expected learning objectives:

- Identify the need and the type of effluent treatment required to RAS solutions
- Understand the difference of nutrient mass and concentration in a legislative context
- Acknowledge constructed wetlands as a low cost but complex treatment solution
- First hand impression of what sludge is like, and its highly variable activity

Supplementary hand-outs:

1. Mathis von Ahnen, 2013. Introduction to Constructed Wetlands. Short resume describing the historical development, present day use and the mechanisms in the constructed wetlands. Prepared for the Aquabest course. DTU Aqua. 3 pp.
2. Carlos Letelier Gordo, 2013. Introduction to effluent treatment in RAS. A short review of effluent treatment. Prepared for the Aquabest course. DTU Aqua. 9 pp.
3. Jaap van Rijn, 2013. Waste treatment in recirculating aquaculture systems. Aquacultural Engineering 53, 49-56.
4. Karin Suhr, Carlos Letelier Gordo, 2013. Measurement of denitrification rate at different environmental conditions. Manual for the practical laboratory exercise. DTU Aqua.

6.8. Session 4B. Effluent treatment in RAS

The second session on effluent treatment was composed of a lecture part and an exercise part.

The lecture had two Power Point presentations; I. Denitrification and II. RAS sludge hydrolysis. The first lecture covered biological transformations of N and particularly N-removal by denitrification. Environmental factors affecting the denitrification process, and the different types of denitrification filters developed for RAS or wastewater treatment systems were reviewed. The advantage of having a controlled filter/reactor that can be manipulated versus an uncontrolled open passive system as natural wetlands was discussed.

The second lecture covered the treatment of the solid waste discharged in RAS and how part of this sludge can be used as a carbon source for fueling denitrification; sludge hydrolysis and fermentation of C-units to volatile fatty acids (VFA). Dynamics of the nutrients (N and P) while remineralizing was also shown.

In the last part of the session, data from the laboratory exercise were processed, and additional small exercises on dimensioning of constructed wetlands and denitrification filters in RAS systems were performed.

Expected learning objectives:

- Link the intensity of recirculation (water use) in RAS with the nitrate concentration
- Distinguish end-of-pipe from in-line denitrification
- Name the biological process that produces VFAs
- Know the difference between aerobic and anoxic conditions for denitrification, and effect of temperature on denitrification

Supplementary hand-outs:

1. van Rijn, J., Tal., Y., Schreier, H.J., 2006. Denitrification in recirculating systems: theory and applications. Aquaculture Engineering 34, 364–376.
2. Suhr, K.I., Pedersen, P.B., Arvin, E. 2013. End-of-pipe denitrification using RAS effluent waste streams: Effect of C/N-ratio and hydraulic retention time. Aquacultural Engineering 53, 57– 64.

7. Course-evaluation

At day 5, prior to departure for Farmers Day in Aalborg, all participants met to evaluate the RAS short course. The evaluation took form as an open dialogue and included an anonymous written evaluation. Out of the 22 participants, 21 delivered a detailed answered questionnaire. One participant provided instead an extended written feedback by mail and addressed matters of importance from his point of view.

Organizers course evaluation

From the organizers point of view, this first short course was a very positive experience. From Day 1 and throughout the entire course, all participants were highly motivated and provided plenty of relevant comments and questions. There was an open atmosphere allowing all to participate and give input and despite the heterogeneity of the participants (nationality, age, educational back ground and work experience etc.) the group appeared consistent. A broad theoretical background and relevant practical expertise accelerated the achievement of learning objectives and improved the out-come.

Group photo with most of the participants assembled at Grenen, Skagen.

Looking back, a more thorough introduction of each participant including introduction of their area of expertise and course expectations could have even further improved the networking and RAS-issue related problem solving. Despite a limited period of time to cover wide-ranging topics of RAS we consider the learning objectives were achieved, and we found that the course had a good balance of lectures, excursions, exercises and seminars.

Strengths-**W**eakness-**O**ppertunities-**T**reats (**SWOT** of the course)

Strengths:

- 10 dedicated lecturers all with hands-on experience on current issues of RAS
- Good facilities (Hotel Skaga, lab facilities and experimental facilities and RAS systems)
- A highly motivating group of participants with valuable experience and input

Weakness:

- The program was too tight; hard to find time to have specific discussions and/or relax
- By covering a broad range of topics, there is a risk that some lectures are irrelevant to some participants.
- The course requires participants with a certain level of RAS experience

Opportunities:

- Transfer of knowledge by hands-on experience and expertise (practice met science)
- A recurring event where BSR networking can be promoted, developed and maintained
- Collaboration in EU projects with different national representatives
- Short courses could ideally target administration/legislation issues based on Danish experience.

Threats:

- If not subsidized, potential costs of participation may exclude some BSR members, i.e. SME companies and non-governmental participants

Participants´ evaluation

The following is extractions of the written feedback based on the evaluation forms

<u>Question 1</u>: How worthwhile was the course in general?

Approx. 95 % of the participants replied that the short course was very good or excellent (fig 1.).

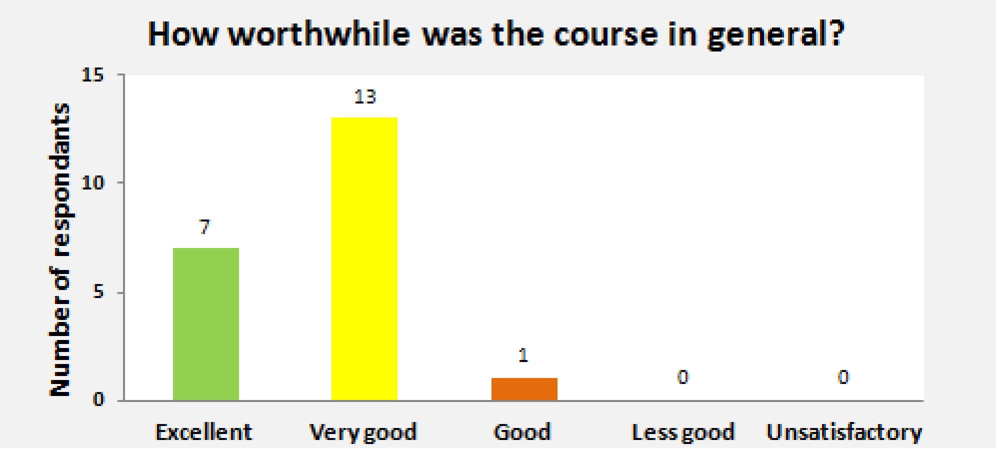


Fig. 1. Approximately 95% of the participants replied that the short course was very good or excellent.

<u>Question 2</u>: Which part of the course did you find the most worthwhile?

There were positive responses on the lectures specific and the entire course in general. Based on the questionnaires it was found that real life examples caught particular attention. For some participants focus on effluent treatment was of high priority, whereas others tended to prefer issues related to system operation and management practice. Some participants explicitly mentioned the benefits on introducing excel tools to predict water quality based on feed and feed loading.

> ”Familiar atmosphere within the course between lectures as well as participants”

<u>Question 3</u>: Which part of the course did you find the least worthwhile?

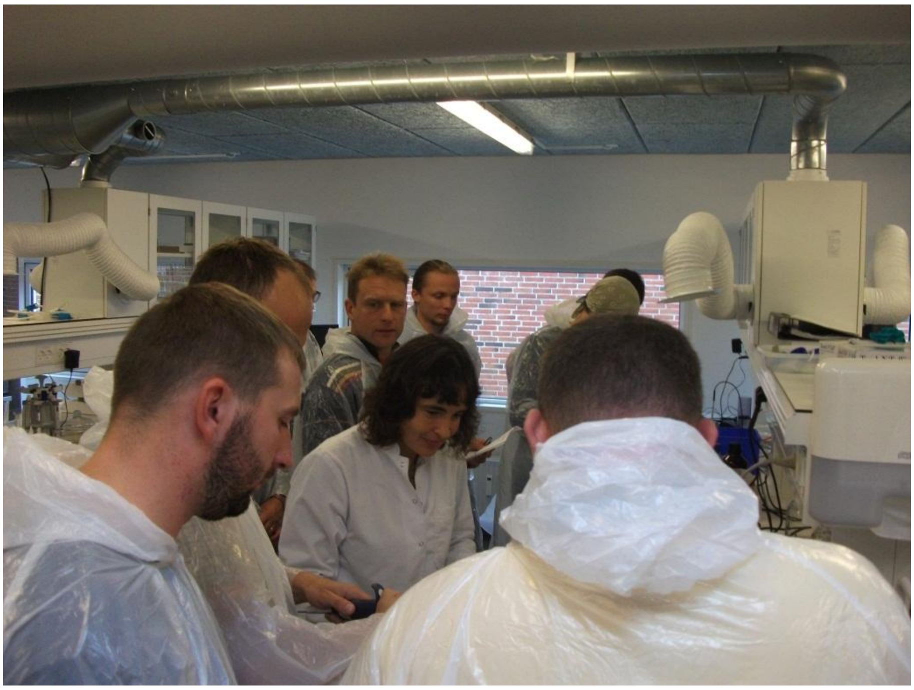
Calculation exercises were considered the least worthwhile due to the tight time schedule among some of the participants. However, a couple stated on the contrary, that the calculations made were among the most worthwhile. Some participants found the topic of toxic micro algae of minor interest, and some participants left the question unanswered.

> ”Presenters had a wide range of understanding about the level and interests of the group”

Question 4: Do you have suggestions for improvement?
Some specific comments are listed below:

- Some of the examples could be more from real, commercial fish farms
- More practical discussion
- Visit a model trout farm; see an operating fish farm with components (six replies)
- More practical examples and demonstration
- To go more deeply into salt water issues
- Less detailed exercises
- Something on energy consumption and total production costs
- Short presentation from/of each participant
- Group work/discussion on problem solving in practice

”More rule of thumbs on what is the costs for different measures – as the fish has to pay the bill”



Laboratory experiments

Question 5: Further comments?

The majority of all participants explicitly stated the course was very well organized.

”Keep spreading knowledge”

Conclusion of the evaluation is that the course had an open and familiar atmosphere and allowed discussion of topics. For a potential next course, all participants will be provided with written information about the participants and the lectures at Day 1.

This could facilitate even faster networking and specific problem solving within the group. Presentations might be handed on a USB keys, however there are some copy right issues that needs to be addressed.

> ”Possibility to participate in following courses would be appreciated”

The Farmers Day following the evaluation provided lots of technical and practically oriented information for the participants that allowed them to further establish a network and share expertise. The majority of the participants joined the following Nordic Network (www.NordicRas.net), though not directly a part of the short course and hence not evaluated here.

Appendix 1: Aquaculture questionnaire

Denmark

Aquaculture questionnaire

Aquaculture production in Denmark	**2002**	**2012**
Annual production (Metric tonnes)	~ 40.000	~ 40.000
Number of fish farms	275	~ 220
Main species	Trout (> 90%), eel	Trout, eel (shell fish, pike perch)
Relative share of RAS / water reuse systems	< 5 %	~30 % in volume
Production (Metric tonnes, MT) and relative share of brackish/saltwater systems	10.000 MT in net pens (~25 %)	10.000 MT in net pens + few large scale SW RAS
Critical issues for production expansion	Not optional	Locations, effluent
Other remarks	Fixed feed allocation	Effluent control

Germany

Aquaculture production in Germany	**2005**
Annual production (tonnes)	~ 44.685
Number of fish farms	12.300 (\`part-time\`, 2003) 732 (exclusive fish farms, 2003)
Main species	Rainbow trout (24.000 T) Common Carp (15.711 T) Blue mussel (9.470 T)
Numbers and relative share of RAS / water reuse systems	31 (< 1%)
Relative share of brackish/ saltwater systems	Almost non-existent (only few regional coastal drainage systems mainly for stocking purpose + few SW RAS for experimental scale)
Critical issues for production expansion	Unfavourable economic conditions e.g. increasing restrictions of environmental & animal protection, high for energy & labour shift of consumer preferences low priced imports limited space for marine/coastal aquaculture (almost harsh conditions along North Sea coast)

Belarus

Aquaculture questionnaire

Aquaculture production in Belarus	2002	2012
Annual production (Metric tonnes, MT)	~ 8.000	~ 18.000
Number of fish farms	20	~ 30
Main species	~ 95 % carp	~ 85 % carp ~ sturgeon, trout, catfish
Relative share of RAS / water reuse systems	< 0.5 %	~5 % in volume
Relative share of brackish/saltwater systems	only fresh water	only fresh water
Critical issues for production expansion	-	The high cost of electricity. Unreliable tech-nology.
Other remarks	-	The high cost of imported feed. Low quality feed from Belarus

Poland

Aquaculture questionnaire

Aquaculture production in Poland	**2002**	**2012**
Annual production (Metric tonnes)	~ 32.000 MT	~ 36.000 MT
Number of fish farms	~ 200	~ 250
Main species	Trout, Carp (> 99%)	Trout, Carp (> 95%)
Relative share of RAS / water reuse systems	0	< 1 % in volume
Relative share of brackish/saltwater systems	0	0
Critical issues for production expansion	Location (amount of water), lack of financing	Legislation, administrative burdens, Lack of financing, public environmental approval, diseases

Estonia

Aquaculture questionnaire

Aquaculture production in Estonia	2002	2012*
Annual production (tonnes)	~ 258	~ 374
Number of fish farms	~15 1 RAS unit	~23 8 RAS units
Main species	Trout (> 80%), carp eel	Trout (~ 65%), (sturgeon, carp,…)
Relative share of RAS / water reuse systems	< 2 %	~40 % in volume
Relative share of brackish/saltwater systems	(~20 %) 1 net pens unit. 1 flow trout unit	0%
Critical issues for production expansion	-	Lengthy adminis-trative license procedure for the construction of the sea (- 3 years)
Other remarks	-	pollution charges (taxes)

Finland

	1993	2002	2012
Aquaculture production (Metric tonnes)	19.000	16.000	12.000 (85% sea net-cages)
Number of fishfarms	510	344	283
Main species	rainbow trout	rainbow trout	rainbow trout > 90%, whitefish (coregonus lavaretus) 8 %
Relative share of RAS / water reuse systems	0 %	0.5%	< 4% (sturgeon, pike perch, whitefish)
Relative share of brack-ish/saltwater systems	50 %	60 %	70 %
Critical issues for production expansion	Limited Licenses, economic downturn	Limited Licenses, efflu-ent control in FW, im-port of red fish meat outside EU	Limited Licenses, efflu-ent control/production profitability in FW, Vi-sion on off-shore ex-pansion /production profitability in SW
Other remarks			

Sweden

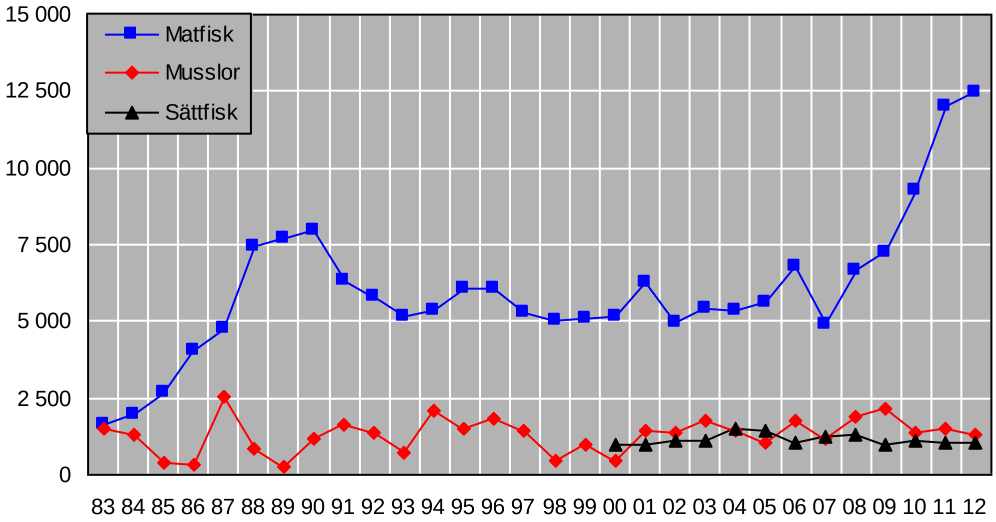
The yield of Swedish aquaculture in 2012 was 10 550 metric tonnes of *food fish*, which when converted to round fresh weight is the equivalent of 12 447 tonnes. The dominating species was rainbow trout (10 499 tonnes in fresh weight), with 84 % of the total production of fish for consumption. The production of char amounted to 1 849 tonnes. The production of eel was estimated at 93 tonnes. Furthermore there were 1 308 tonnes of cultivated blue mussels.

The total value of the aquaculture production of *food fish* amounted to SEK 340 million, an increase with SEK 12 million compared to 2011. The dominating species was rainbow trout with SEK 246 million.

The production of *fish for stocking* was estimated at 1 046 tonnes. The dominating species was rainbow trout with 657 tonnes. The trout production amounted to 246 tonnes and char was estimated at 81 tonnes. The total value of the aquaculture production of *fish for stocking* amounted to SEK 83 million.

For compensatory purposes 2.9 million of fry of salmon and sea trout were released, mainly in rivers running into the Baltic.

The number of persons employed in Swedish aquaculture was estimated at 370 and the total number of working hours at 420 000.



Swedish Aquaculture production, 1983–2012.