Aalto University
School of Engineering

# Biological treatment processes of water and waste

# WAT - E2180

*Anna Mikola  Professor of Practice  D Sc (Tech)*

# Lecture outline

**Course team introduction**

**Participants' introduction**

**Course's learning outcomes**

**Content of the course**

- **Lectures & exercises**
- **Laboratory work**
- **Excursion**

**Introduction discussion: What kind of biological processes do you already know?**

**! 4 groups for the laboratory work**
**→ In MyCourses**

**Pre-exam!!**

**Lab safety!!**

# Lecturer
# Anna Mikola

- **M.Sc. From HUT Water lab 1999**
- **Exchange year in France at ENCR 1994-1995**
- **D. Sc. (Tech.) Spring 2013 Dissertation: The effect of flow equalizationa and prefermentation on BNR**

- **Working experience:**
  - 3 years at Nopon Oy
  - Researcher at HUT/Aalto
  - 18 years with a consultant (Kiuru&Rautiainen Oy, Ramboll Finland)
  - Post-doctoral researcher at Aalto 2013-2018
  - Lived 5 years in Berlin, 4 children
  - Visiting researcher in INSA Toulouse in 2017
  - Professor of Practice since 2018

# The course team

**Course's microbiology content: Dr. Antonina Kruglova**

**Lab reactors: Maria Valtari**

**Course assistant: Oona Kinnunen**

**Lab staff: Aino Peltola, Heikki Särkkä and Marina Sushko**

**Lecturers from the lab:**

**Danielle Bansfield**

**Antonina Kruglova**

**Guest lecturers from Griffin Refineries and Tampere University**

# Participants' introduction

**1 minute each containing e.g.**

- **Background?**
- **Experience with biological processes**
- **Expectations for this course?**

# Learning outcomes

Knowledge

Skill

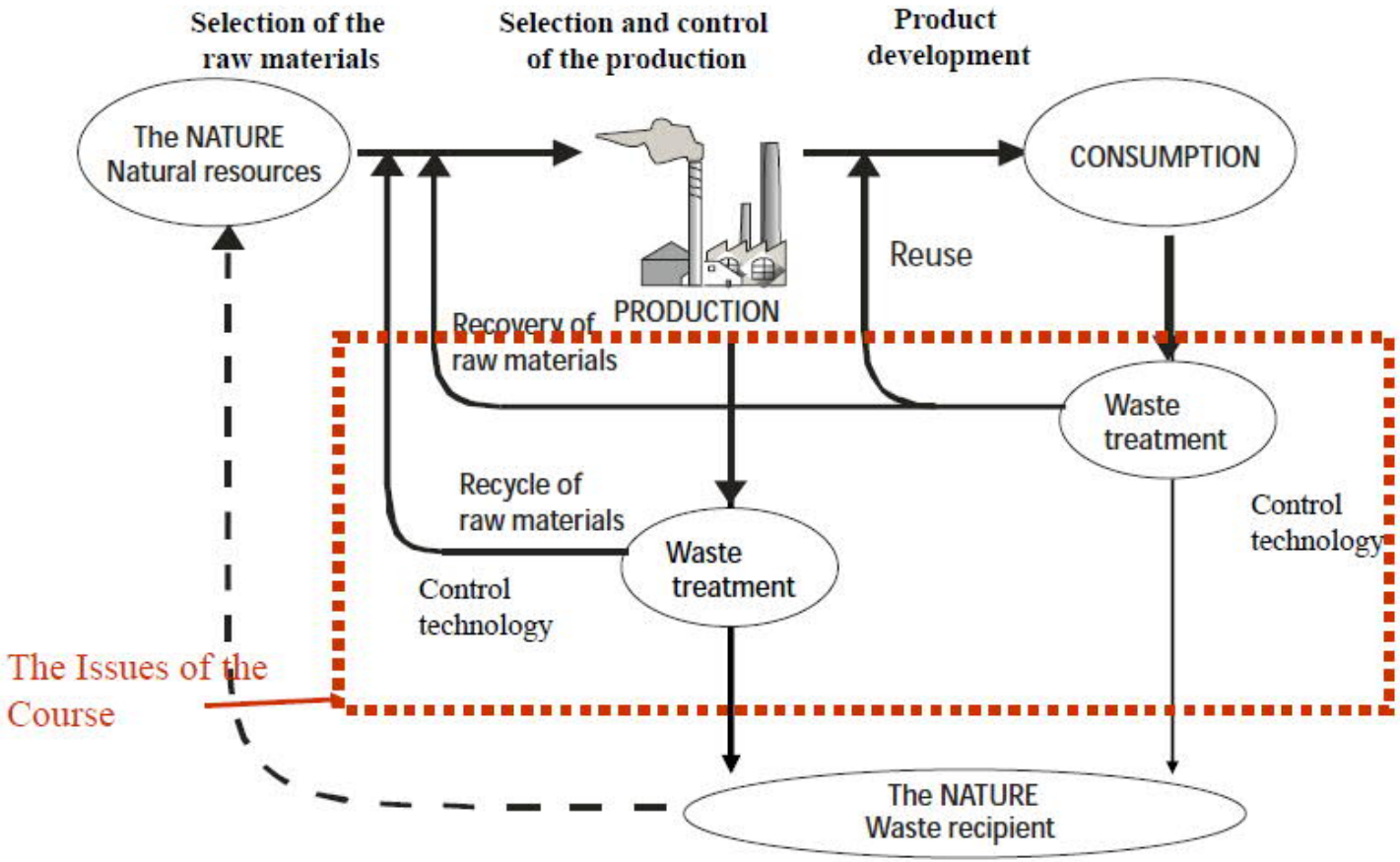
**Upon completion, the student should be able to:**

1) **Describe the most important biological water, wastewater, sludge, waste and gas treatment processes**
2) **Explain biochemical, microbiological and ecological phenomena in biological treatment processes**

3) **Form simple mass balances of biological unit processes**
4) **Identify the critical factors affecting the efficiency of biological treatment processes and describe their control systems**

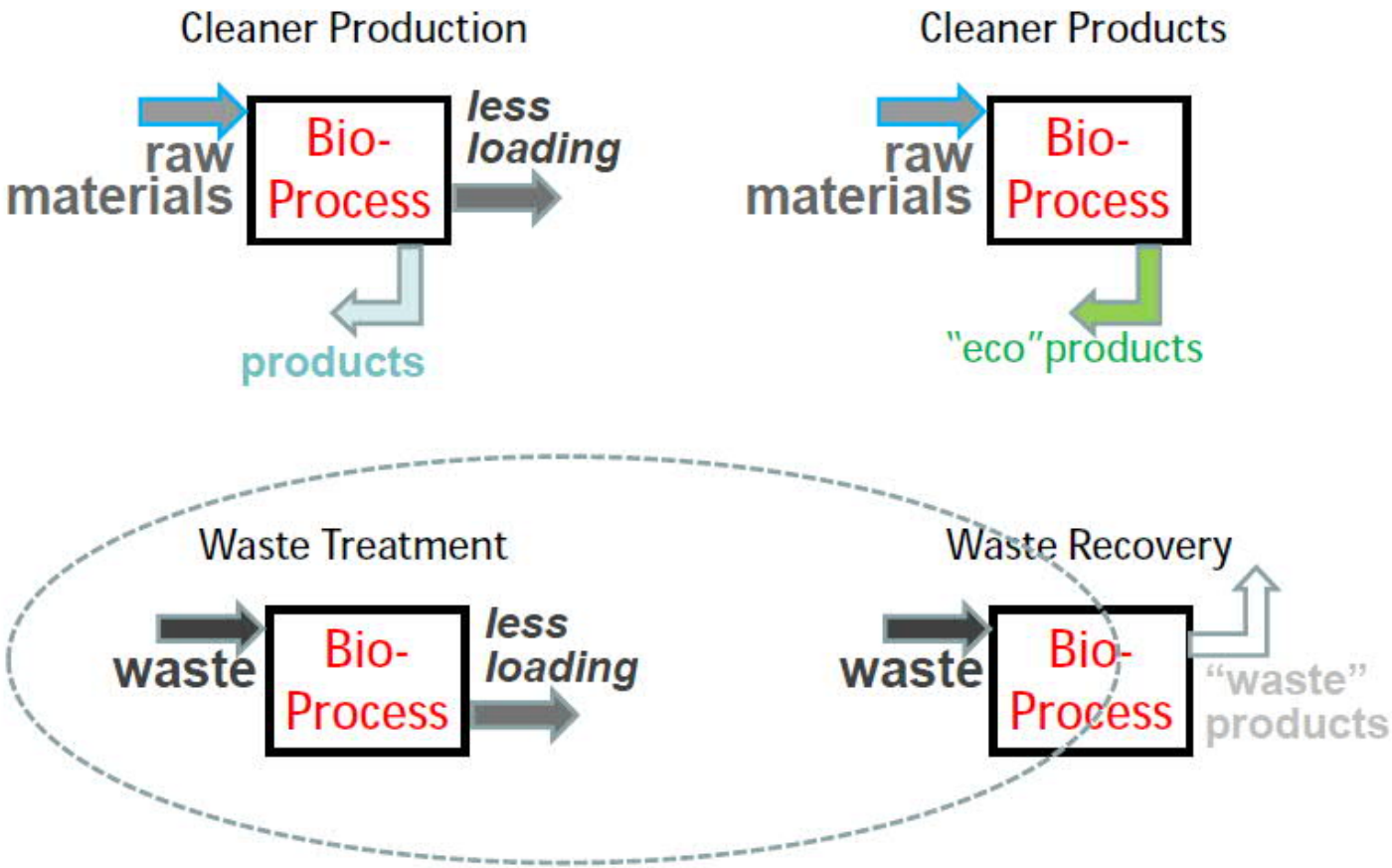
**The focus will be on wastewater treatment but same principles and phenomena are applicable everywhere!!**

# Material flows of the human economy




18.2.2018 Timo Laukkanen

# Environmental Sound Bioprocesses

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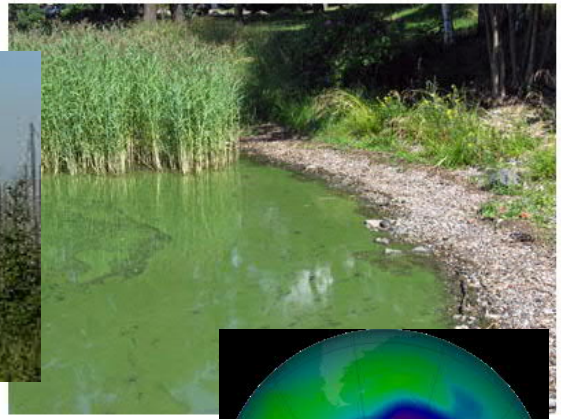
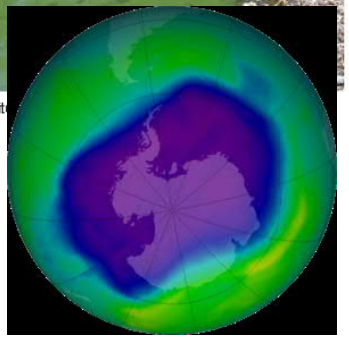
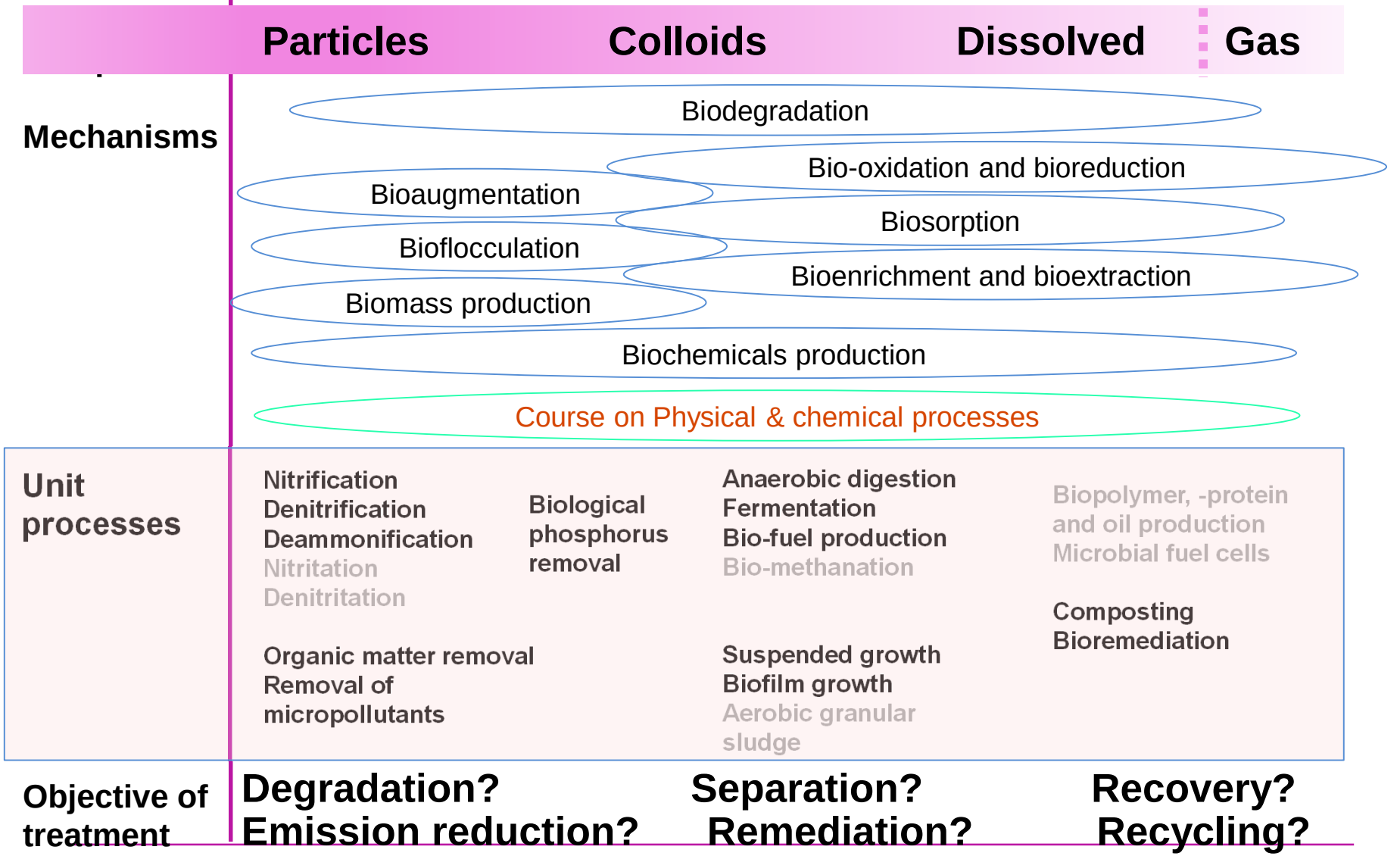
# Environmental challenges to be solved





**Biological = ecology, microbiology and biochemistry**



# Course content

Theoretical knowledge

- Lectures
- “Einstein” exercises
- Lab project

Practical knowledge

- Lectures
- “Worker” exercises

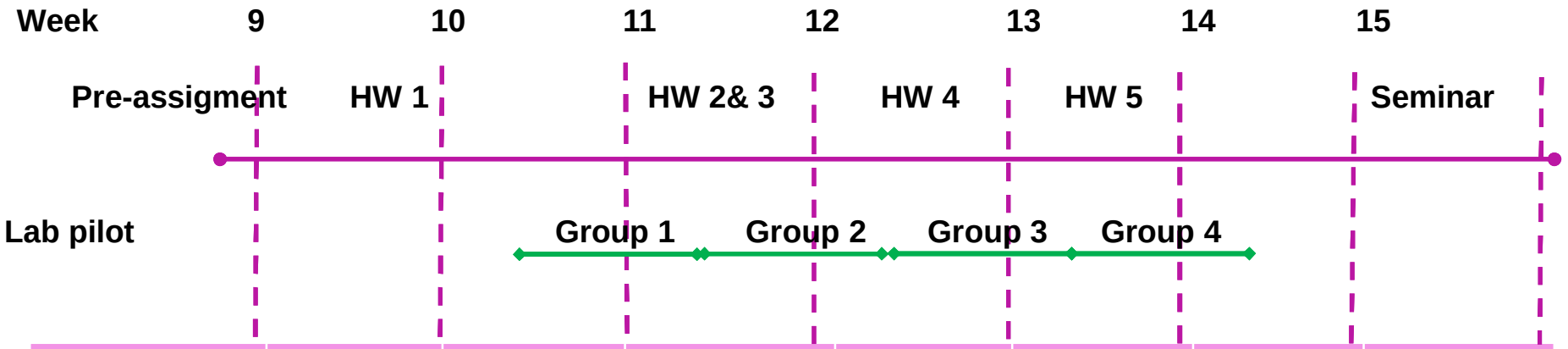
Hands-on knowledge

Laboratory pilot operation

Lab project

Excursion

# Timeline for the course




| | | | | | | | |
|---|---|---|---|---|---|---|---|
| **Lectures** | **Intro** * | | * * | * * | * **Excu** | * * | |
| Exercise DLs | | | HW 1 | | HW 2&3 | HW 4 | HW 5 |
| Exams | | | Exam 1 | Exam 2 | | Exam 3 | Extra 1,2,3 |
| Lab project | | Monitoring & microbiology lab Group 1 | Group 2 | Group 3 | Group 4 | | |
| Presentation | | | | | | Support session | Final presenta-tions |
| Written report | | Lab work quiz | | | | | |

# Course content – lectures, exercises and exams

- **Lectures and exercises**
  - Lecture sessions: 3.5 hours Tuesday afternoon at 13:00 and Thursday morning at 8:30
  - Each session will be divided into several interactive lectures, demo exercises and group discussions
  - For many sessions some reading material will be given before
  - Pre-assigment + Lectures 2: Microbiology
  - Lecture 3-8: Basic process principles, process design and applications
  - Homework exercises from most of the sessions (5 sessions, totally 20 exercises)
  - The content will be divided into theoretical and practical parts

 &  symbols

- **Three mid-term exams**
  - 60 min in the beginning of three sessions (16.3., 30.3., 8.4.)
  - One extra during the last week

→ objective to learn the theory and design principles of the processes

# Support sessions for homework exercises

**With Oona in the course**
**ZOOM** https://aalto.zoom.us/j/66513544559

- **Tuesdays at 9:30 until 11:30**

# Course books

## Biological wastewater treatment

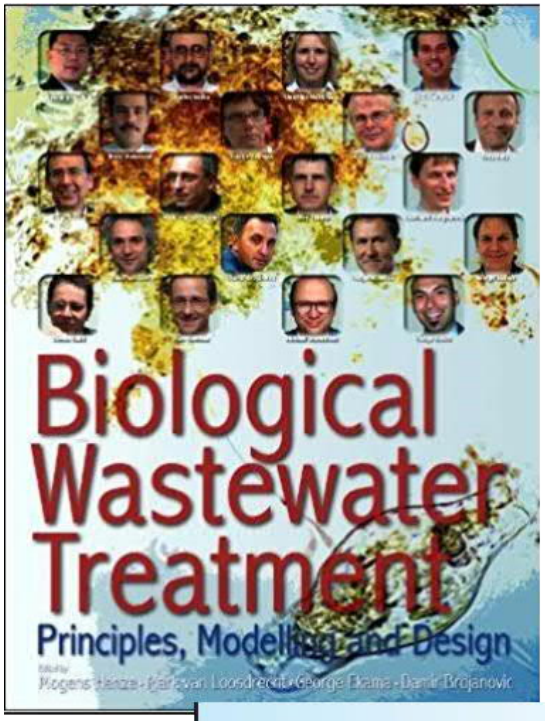
**Author(s) / Editor(s) Henze, Mogens; Loosdrecht, Mark C. M. van; Ekama, George A.; Brdjanovic, Damir**

**Publisher IWA Publishing**

**Copyright Date 2008**

**ISBN 978-1-84339-188-3**

**Electronic ISBN 978-1-68015-582-2**




## Environmental biotechnology

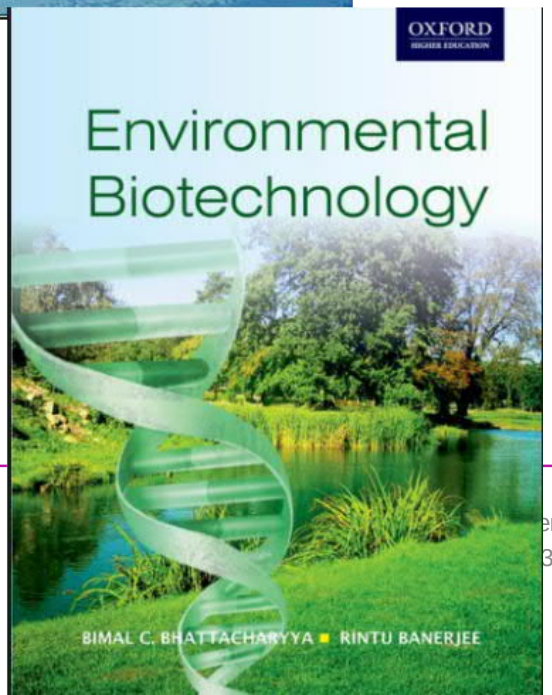
**Author(s) / Editor(s) Bhattacharyya, Bimal C.; Banerjee, Rintu**

**Publisher Oxford University Press**

**Copyright Date 2007**

**ISBN 978-0-19-568782-8**

**Electronic ISBN 978-1-61344-143-5**




## Both available as eBook

# Course content – lab project

- **Laboratory work**
  - Task: to operate and monitor two lab reactors during four weeks in different conditions
  - Week 2: Introduction to basic monitoring and microbiology→ lab work quiz
  - Weeks 2-5: Four groups of students will operate the reactor in different conditions (oxygen, temperature, total N removal, bioP)
  - Week 6: Scientific papers
  - Week 7: Presentation
- **Virtual 360 º excursion and a presentation**
  - Virtual visit to Viikinmäki wastewater treatment plant on Thursday 1.4.
  - WWTPcatching at the plant
  - → Objective to understand the theories and design principles in practice, to learn about the process monitoring and to assess, present, plan and report practical laboratory work.

# Lab project

Week 1
Orientation to lab project

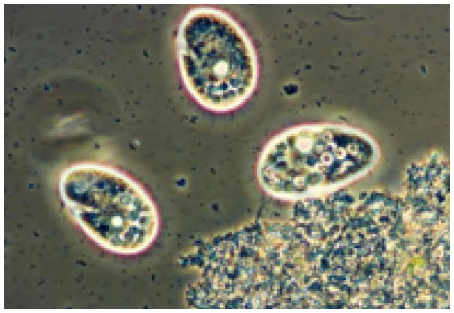
Week 2
Monitoring and microbiology lab (2x4h)
Group 1 operates the reactors (2h/d)

Week 3
Group 2 operates the reactors (2h/d)

Week 4
Group 3 operates the reactors (2h/d)

Week 5
Group 4 operates the reactors (2h/d)

Week 6-7
Analysis of the results, poster and presentation



**Content and objectives, linking to theory**

**Learning the basic monitoring,**

**Focusing on microbiology**

**Presenting the results, learning from each other, feedback**

**Students operating the reactors independently**

**Conditions: 1: DO 2: Anoxic 3: Anaerobic 4: Temperature**

Aalto-yliopisto
Aalto-universitetet
Aalto University

# Reactor operation and monitoring


Reactors:
Sequencing bacth reactor SBR and membrane bioreactor MBR

- Objective: Study two different suspended growth reactors with different sludge age during 4 weeks

- Monitoring process conditions, effluent water quality and sludge characteristics

- Week 1: Effect of oxygen
- Week 2: Implementation of anoxic sequence in the SBR
- Week 3: Implementation of anaerobic sequence in the SBR
- Week 4: Effect of temperature
- Influent water: synthetic wastewater

# Detailed schedule for groups

| Tasks: | | |
|---|---|---|
| Microscoping 1h | | Antonina |
| Plating 0,5 h | | Oona |
| Lab reactors 0,5-1,5h | | Maria |
| Plate counts 0,5 h | | Oona |
| | | |
| Arrivals and transferring between tasks: Aino and Marina | | |

| DAY 1 Tuesday 9.3. | | | | |
|---|---|---|---|---|
| Group | 1 | 2 | 3 | 4 |
| | | arrival 12:45 upstairs | | arrival 12:45 |
| 13:00 | arrival 13:15 | | | |
| 13:30 | | | | |
| 14:00 | | | arrival 14:00 | |
| 14:30 | | | | |
| 15:00 | | | | |
| 15:30 | | | | |
| 16:00 | | | | |
| 16:30 | | | | |

| DAY 2 Thursday 11.3. | | | | |
|---|---|---|---|---|
| Group | 1 | 2 | 3 | 4 |
| | | arrival 8:15 upstairs | | arrival 8:15 |
| 8:30 | arrival 9:00 | | | |
| 9:00 | Monitoring tasks | | arrival 9:15 | |
| 9:30 | Monitoring tasks | | | |
| 10:00 | | | | |
| 10:30 | | | | |
| 11:00 | Monitoring tasks | | | |
| 11:30 | Monitoring tasks | | | |
| 12:00 | Monitoring tasks | | | |

NOTE! It is very important to arrive at the indicated time. Students arriving late will not be let in!!

# Individual work
# Lab work quiz DL 16.3.2021

- **Short quiz on monitoring methods**
- **Purpose:**
  - Help you with the monitoring work during your week
- **Answered in MyCourses and evaluated**

# EXCURSION

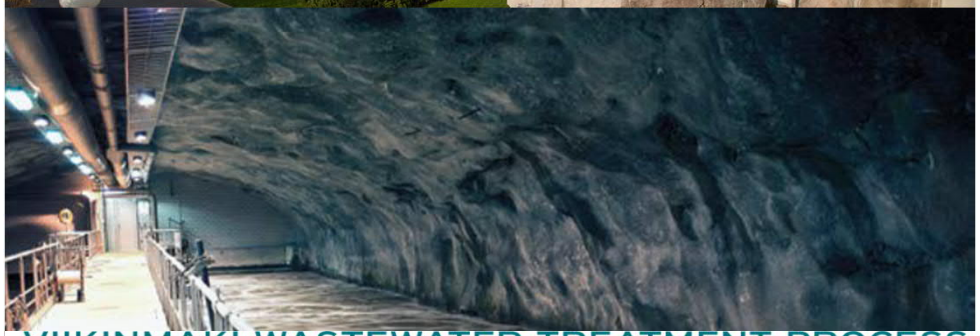
**To Viikinmäki wastewater treatment plant**

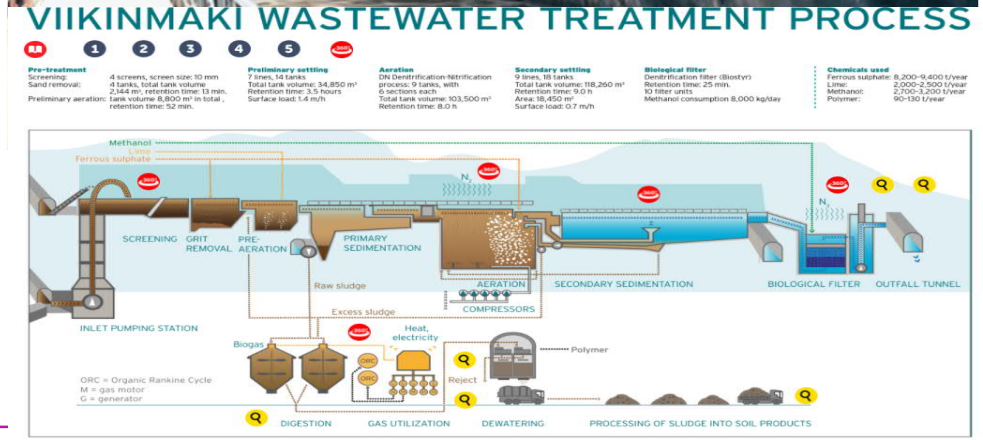
**THURSDAY 1.4. during the course teaching session**

**Virtual 360º visit**

**Presentation and Q&A by Anna Kuokkanen**

**Some assignments during the visit**






**Pictures: HSY**

# Seminar – Group work
# Tuesday 13.4. at 13:00

- **Three roles in the groups:**
  - Presenters
  - Competitors
  - Planners
- **Three outcomes:**
  - Presentation of the lab study
  - Presentation of another study (from the literature)
  - Experimental plan and expected outcomes for your further study

- **Presentations: 10 min + 10 min + 10 min**
- **Discussion (10 – 15 min)**

# Forming the groups for the lab work

**Some boundary conditions:**

- **Responsibility over the reactor during one week**

- **4 groups (1,2,3 and 4) for each week of the pilot operation (from Tuesday to Tuesday)**
- **Each group decides the monitoring (2 - 3 hours per day) schedule and informs the lab (submitted in MyCourses)**

# Workload

| Learning activity | Workload calculation (hours) | Remarks |
|---|---|---|
| Lectures + excu | 35 | 10 x 3,5 hours |
| Exercises | 10 | Support sessions (not obligatory) |
| Home assignments | 15 | 3 hours per homework assignment |
| Reading materials | 10 | 5-10 pages for each session (5 sessions) |
| Lab project work | 34 | 12 hour in the lab, 4 hours in presentations, 20 h for preparing, reporting and preparing the presentation |
| Midterm exam (3x) | 15 | 4h preparation for each mid-term exam + 1h writing the exam |
| Independent reflection | 15 | |
| In total | 134 | |

## Our attempts to reduce the workload:

- Good instructions and clear separation between theoretical and practical assignments
- Clear links and supporting elements between different assignments
- Motivating and inspiring course content

# Communication

- MyCourses -page
  - Lecture material available mostly before the lecture
  - Instructions for homework assignments
  - Submission of home assignments & grades
  - Information and submissions for the lab project
- Communicating
  - *Whole course*: Teams, MyCourses & email
  - anna.mikola@aalto.fi, Antonina.kruglona@aalto.fi, maria.valtari@aalto.fi , oona.s.kinnunen@aalto.fi
  - *Within the groups: Teams,* please organize the communication within the group already in the beginning!

# Course grading

- **40 % mid-term exams - 3 exams 20 points each**
- **30 % lab project (quiz, excursion assignment, presentation)**
  - 1/3 from the individual part, 2/3 from the group work
  - Grading scale 1 – 5
  - The same grade for the whole group unless the group communicates differences in contribution
- **30 % homework exercises**
  - 5 exercises, 75 points total
- **Bonus possibility up to 0.5 grade when attending the lectures**
- **NOTE!! Late submission – 1 week → 50% off, more → 100% off**

*Grading thresholds:*

**1**-40% of total points **2**-52% **3**-64% **4**-76% **5**-88%

# Important to do after the introduction lecture

**Register to one of the groups 1 - 4 in MyCourses**

**Answer the pre-exam quiz in MyCourses**

**Check that you lab safety is in order**

**Decide how to communicate with your group members (1-4) – Teams group or something else?**

**Start planning your monitoring week shedule (2 students – 2-3 hours every day during your week)**

**Submit the schedule in MyCourses**

# Biological processes

# What kind of biological processes in environmental engineering do you already know?

**Discussion in groups**

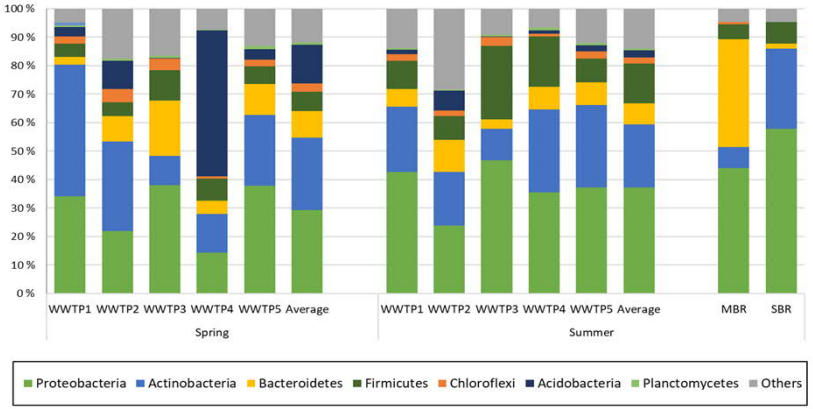
# Examples of on-going research

# Development of cold-climate treatment processes using microbial population information

I. Bacteria of low-temperature processes (Postdoc Antonina Kruglova, PostDoc Alejandro Gongalez-Martinez, M.Sc. Jenni Kesulahti, M.Sc. student Khoi Le Minh)

II. Comparison of conventional activated sludge with advanced activated sludge community (PostDoc Antonina Kruglova)

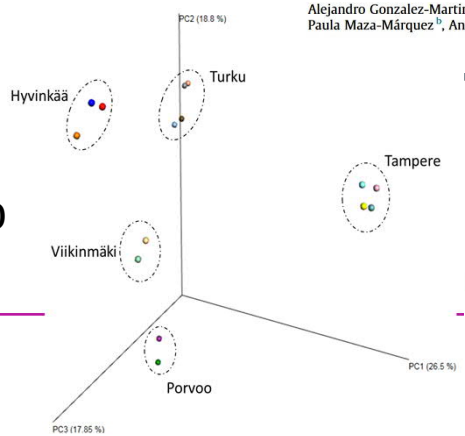
III. Aerobic granular sludge in low temperatures (PostDoc Alejandro Gongalez-Martinez)





Start-up and operation of an aerobic granular sludge system under low working temperature inoculated with cold-adapted activated sludge from Finland

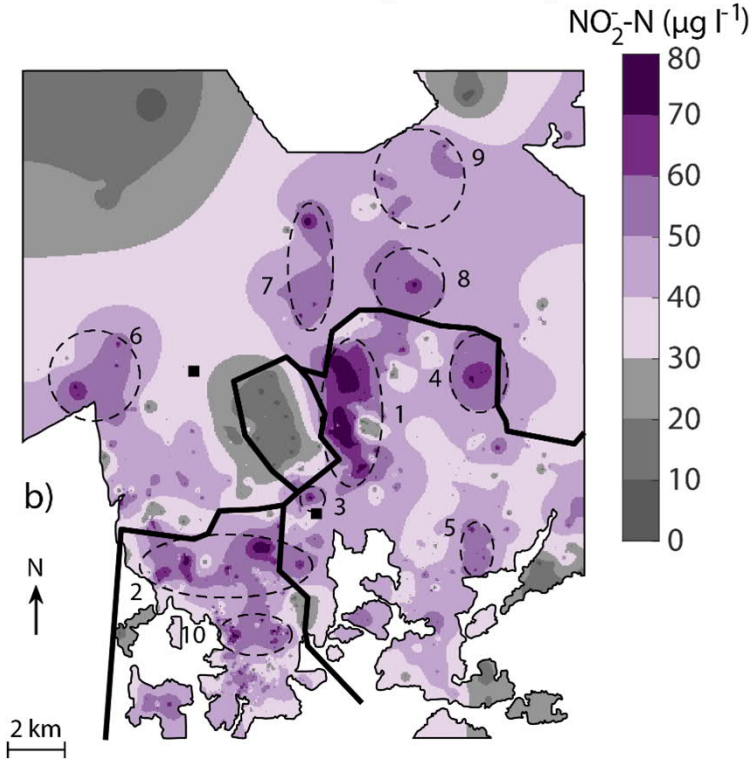
Alejandro Gonzalez-Martinez [a,*], Barbara Muñoz-Palazon [b], Alejandro Rodriguez-Sanchez [b], Paula Maza-Márquez [b], Anna Mikola [a], Jesus Gonzalez-Lopez [b], Riku Vahala [a]




# Water Supply

**In drinking water quality the focus is in the role of natural organic matter in the water quality changes in the distribution system.**

- The influence of organic matter on nitrification in the drinking water distribution system (Lic. Tech. Pirjo Rantanen)




Scientific Research Publishing

Journal of Water Resource and Protection, 2017, 9, 1026-1042
http://www.scirp.org/journal/jwarp
ISSN Online: 1945-3108
ISSN Print: 1945-3094

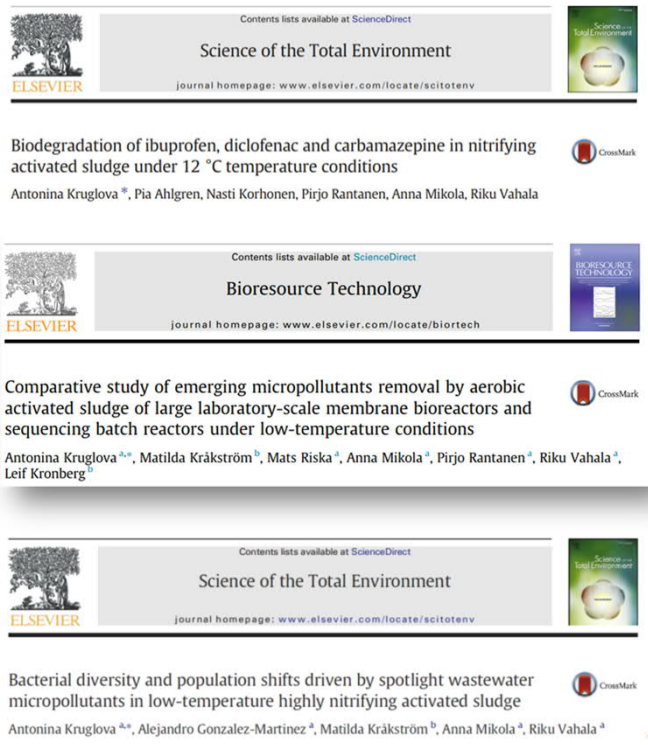
## The Spatial Distribution of Nitrite Concentrations in a Large Drinking Water Distribution System in Finland

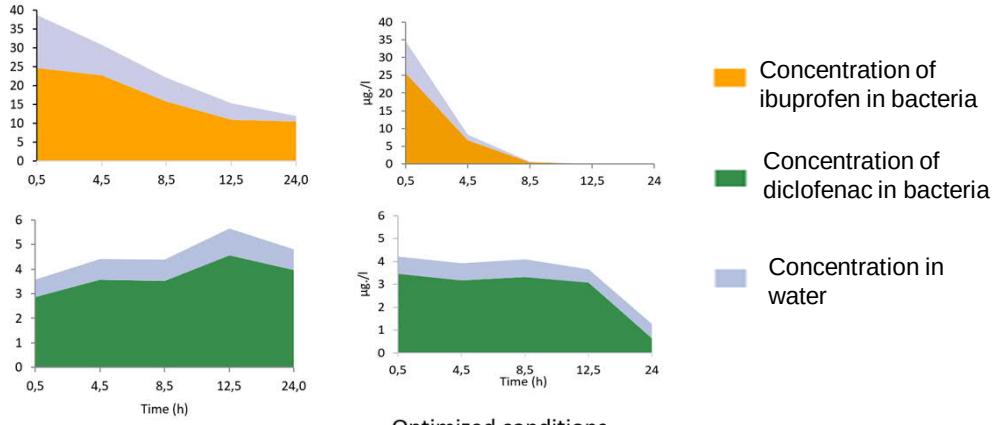
**Pirjo-Liisa Rantanen[1*], Minna M. Keinänen-Toivola[2], Merja Ahonen[2], Ilkka Mellin[3], Duoying Zhang[4], Tuula Laakso[5], Riku Vahala[1]**

[1]Department of Built Environment, School of Engineering, Aalto University, Espoo, Finland
[2]Faculty of Technology, Satakunta University of Applied Sciences, Rauma, Finland
[3]Department of Mathematics and Systems Analysis, School of Science, Aalto University, Espoo, Finland
[4]School of Civil Engineering, Heilongjiang University, Harbin, China
[5]Helsinki Regional Environmental Services Authority, Helsinki, Finland

# Enhanced treatment of micropollutants from wastewater

Optimization of micropollutants biological removal at low temperatures

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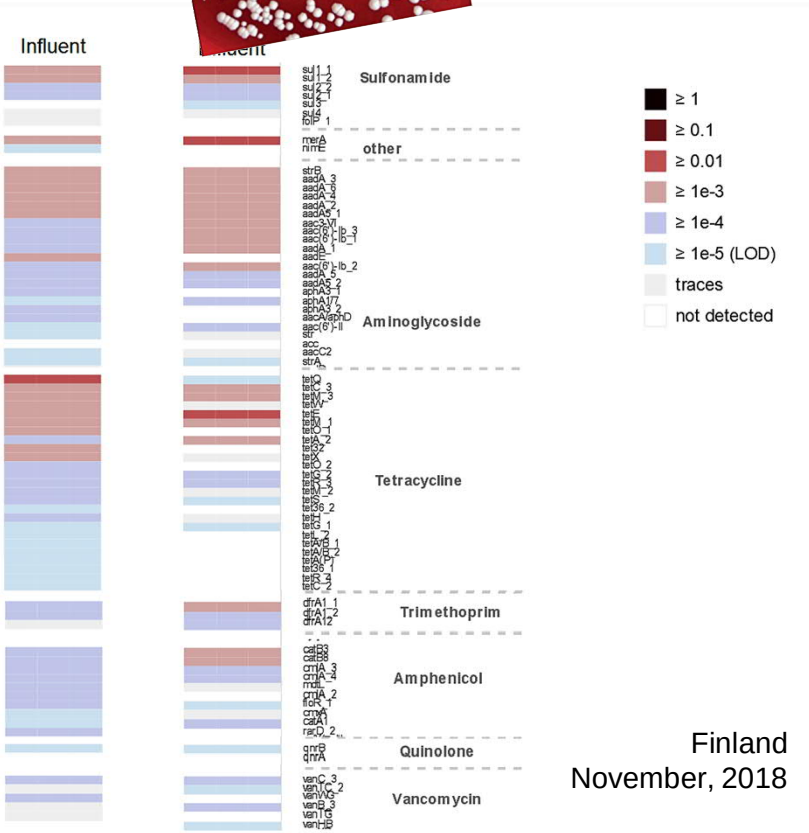
# Antibiotics and antibiotics resistance bacteria in wastewater treatment

- Global antibiotics resistance crisis
- WWTPs are among the main sources of antibiotics resistance in the environmental
- Removal rates in wastewater treatment are highly dependent on process conditions and temperature

(*Kruglova et al., 2014, Kruglova et al., 2016*)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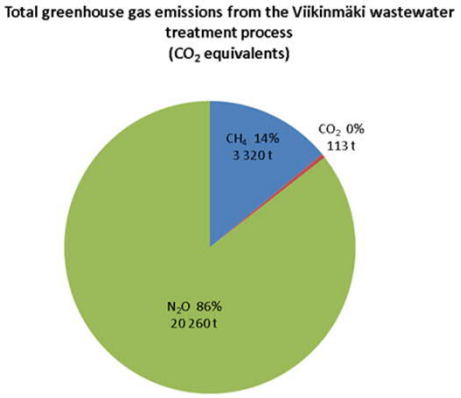
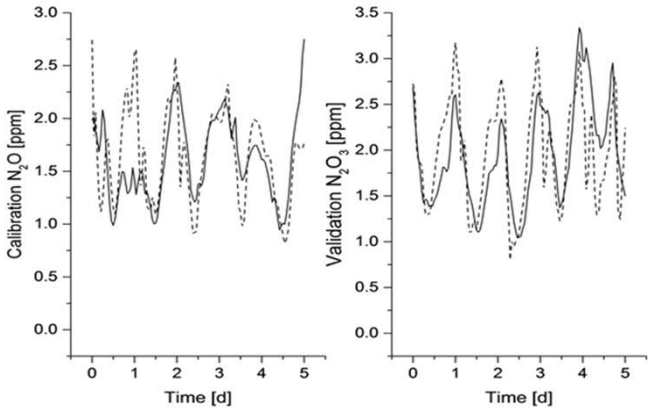
Finland
November, 2018

# GHG emission studies from advanced nutrient removal processes

**Comprehensive inventory of $N_2O$ emissions from an advanced WWTP and implementation of $N_2O$ in the plant wide process model (Collaboration with HSY)**




ENVIRONMENTAL Science & Technology

Article

pubs.acs.org/est

Nitrous Oxide Production at a Fully Covered Wastewater-Treatment Plant: Results of a Long-Term Online Monitoring Campaign

Heta Kosonen,[†] Mari Heinonen,[*,‡] Anna Mikola,[†] Henri Haimi,[†] Michela Mulas,[†,∥] Francesco Corona,[‡,⊥] and Riku Vahala[†]

# Smarter monitoring of micropollutants from wastewater

- Screening of wastewater toxicity based on Effect-Directed Analysis (EDA) (PhD Pia Välitalo)

Contents lists available at ScienceDirect

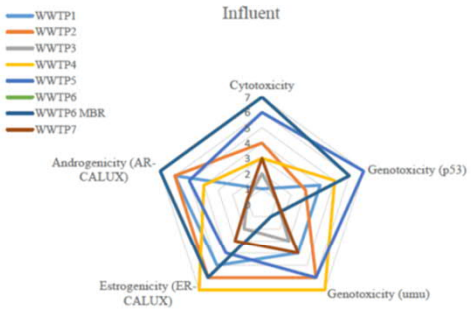
Water Research

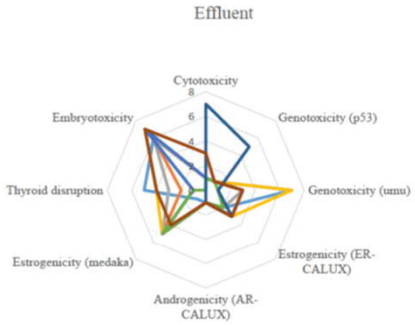
journal homepage: www.elsevier.com/locate/watres

Estrogenic activity in Finnish municipal wastewater effluents

Pia Välitalo [a, b, *], Noora Perkola [a], Thomas-Benjamin Seiler [c], Markus Sillanpää [a], Jochen Kuckelkorn [c], Anna Mikola [b], Henner Hollert [c], Eija Schultz [a]

[a] Finnish Environment Institute, Laboratory Centre, Hakuninmaantie 6, 00430 Helsinki, Finland
[b] Aalto University, Department of Civil and Environmental Engineering, Tietotie 1E, 02150 Espoo, Finland
[c] RWTH Aachen University, Department of Ecosystem Analyses, Institute for Environmental Research, Worringerweg 1, 52074 Aachen, Germany




Water Research 126 (2017) 153–163

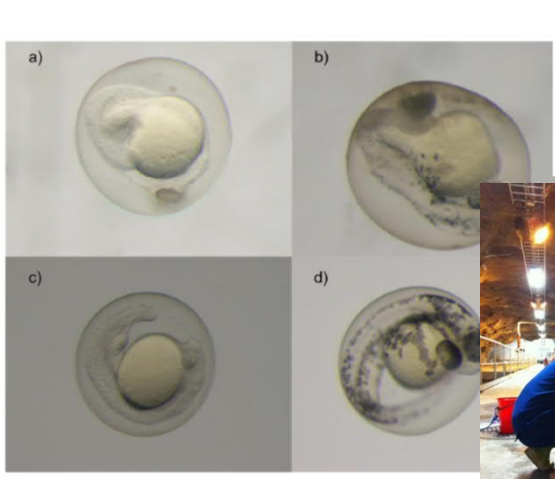
Contents lists available at ScienceDirect

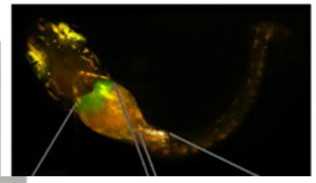
Water Research

journal homepage: www.elsevier.com/locate/watres

Effect-based assessment of toxicity removal during wastewater treatment

Pia Välitalo [a, b, *], Riccardo Massei [c, d], Ilse Heiskanen [a], Peter Behnisch [e], Werner Brack [c, d], Andrew J. Tindall [f], David Du Pasquier [f], Eberhard Küster [c], Anna Mikola [b], Tobias Schulze [c], Markus Sillanpää [a]



# New project on phosphorus recovery

- How to optimize the formation of vivianite in the biological processes?
- How to enhance the recovery?
- How to enhance resource efficiency of metal coagulants in the processes?
- A joint doctoral project with Aalto and INSA Toulouse
- Utility partners: HSY and SIAAP

Iron present in AD feed (concentration and form depending on WWTP process (CPR))