Process Engineering Ib (Biological Processes Application)

Fall semester 16

D-BAUG, Environmental Engineering Master 1. Sem.

https://moodle-app2.let.ethz.ch/course/view.php?id=2540

Outline / General Information

Lecturers:

Prof. Dr. Eberhard Morgenroth

Lecture:

7.11.16 – 21.12.16
Monday 9:45-11:45
Wednesday 8:00-10:00

Number:

102-0217-01L

Credits:

3 CP

Assistant:

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Assistant's consultation-hours:

Monday: 14.00 – 16.00
Wednesday: 14.00 – 16.00
Thursday: 09:00 - 11.30
or by appointment

Industry expert:

Kim Sorensen
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Course purpose

This is a 7 week course during the second half of the semester. The purpose of this course is to build on the fundamental understanding of biological processes and wastewater treatment applications that were studied in Process Engineering Ia. Case studies that are jointly discussed in class and student led projects allow you to advance the understanding and critical analysis of biological treatment processes.

Course objectives By the end of the course, you should be able to do the following:

- Process understanding and process integration. Apply the basic principles you have learned in Process Engineering Ia (102-0217-00L) for design, modeling, and critical assessment. Integrate existing information and extend your knowledge by independent study.

- Scientific or technical evaluation. Identify a specific scientific or engineering question and develop an approach to answer this question using mathematical modeling; provide a critical discussion of your answer; report your results in a research paper and an oral presentation.
- Teamwork. State principles of effective team performance and the functions of different team roles; work effectively in problem-solving teams.
- Communication. Communicate and document your findings in concise group presentations and a written report.

In-class case studies

Together with our industry expert we will be working on a case study during two class sessions. The industry expert will present a case from practice where there is a problem at an existing treatment plant. We will jointly evaluate and discuss possible causes for this problem. We will then use hand calculations and SUMO modeling to test whether the suggested causes could in fact have resulted in the problem and we will evaluate approaches for solving the problem. This case study is an excellent preparation of problem identification and a targeted approach for problem solving in the larger student project.

Student Project

You can learn a lot through listening to your professor (I hope) and reading textbooks (e.g., in Process Engineering Ia). But in your future career you need to do more than knowing the scientific theory and the concepts underlying design and operation. You need to be able to critically evaluate systems, identify the factors limiting system performance, develop approaches to answer scientific or engineering questions, critically discuss your findings, and ultimately communicate your findings to an audience through oral and written communication. Learning and applying these critical design and thinking skills is the focus of the student project.

Here is an overview of the key features of the student project:

- You work in teams of 3 or 4 students.
- Team members are assigned by your instructor based on an initial questionnaire. This assignment of teams will be done during the first 7 weeks of the semester (i.e., during Process Engineering Ia).
- Final products for the student project are an oral presentation and a written paper.
- The instructor provides a list of suggested topics (see section below "APPENDIX: List of suggested themes and specific topics for the student project"). Teams can suggest their own topics, subject to instructor's approval.
- The topics suggested in the appendix are rather broad and not very specific. This is intentional. It is the responsibility of the student teams to develop specific research questions and a feasible research approach. Note that 7 weeks are a very short period of time and it is essential that students identify a very focused question that can in fact be answered in the given time.
- The student project mimics what you would do during a scientific research project (e.g., when you perform experiments during your MSc thesis) or during your first job as a consulting engineer (e.g., when you design, build, start-up, and commission a treatment plant). But instead of performing actual experiments and instead of building

a real plant, you will be using the simulation SUMO to evaluate your research question or to test your suggested system design.

- You can build on what they have learned in the companion course (Process Engineering Ia). But depending on the specific focus of your project you may want to acquire new knowledge through independent study or through discussion with the instructor/teaching assistant. Depending on needs, we can also schedule some on-demand lectures or discussion sessions for some of the groups.
- You should use the simulations platform SUMO to perform experiments in your projects. But – there is also a danger in using such a simulation platform if you use it as a black box. Therefore it is required that you also do hand calculations for simplified systems to critically asses the simulation results. These hand calculations, conceptual models, and verification of the feasibility of modeling results must be included in the report.
- Doing research or working as a consulting engineer is hard. Therefore this course will provide a structure of specific milestones and feedback sessions to support and guide you in this project. At different stages you will receive feedback from your instructor/teaching assistant or peer feedback from another team. See the schedule for dates and types of feedback.

Written paper

The final paper should be between 8 and 15 pages in length (at 1.5 spacing, 12-point font). Additional pages are allowed for appendices that contain detailed computations, drawings, outputs, or exhibits. However, the main text should tell the "complete story" without relying on appendices to present essential information. The paper should be well written in terms of format, usage, grammar, spelling, and syntax. We will evaluate each team's work according to the technical quality of its final product, the quality of the written work against the standard of being suitable for publication in a top-rank journal, and the quality of the oral presentation against the standard of being suitable for presentation at a top-rank technical conference. The quality of the report and oral presentation include the effectiveness of the communication.

The final paper should include the following sections[1]:

- **Abstract:** The abstract should state briefly the purpose of the research, the principal results and major message. An abstract is often presented separately from the article, so it must be able to stand alone. The abstract must be less than 500 words.
- **Introduction:** State the objectives of the work and provide an adequate background, avoiding a detailed literature survey or a summary of the results.
- **Material and methods:** Provide sufficient detail to allow the work to be reproduced. Methods already published should be indicated by a reference: only relevant modifications should be described.
- **Results:** Results should be clear and concise. Show only those experimental results that are relevant to your objectives and conclusions and which you want to discuss.
- **Discussion:** This should explore the significance of the results of the work, not repeat them. It should integrate your findings in a comprehensive picture and place them in the context of the existing literature. A combined Results and Discussion section can be appropriate. Avoid extensive citations and discussion of published literature.

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[1] This list and descriptions are taken directly from https://www.elsevier.com/journals/water-research/0043-1354/guide-for-authors#25000. Thus, from this STUDENT PROJECT you will not only learn about process engineering but also what it takes to write a scientific journal paper.

- **Conclusions:** Conclusions section is mandatory for this journal. Conclusions contain essentially the 'take-home' message of a paper. Conclusions are not an extension of the discussion or a summary of the results. Authors are advised to list important implications of their work in a bulleted list. Conclusions must not contain references to the cited literature.

Oral presentation of final report.

The oral presentation should be suitable for an audience that has a solid understanding of biological process engineering but that has not heard of the specific question you have addressed in your student project (e.g., another student in this course or an engineer from practice). The duration of the oral presentation will be defined (depends on number of students in the class).

Required and recommended reading

Same as Process Engineering Ia. In addition the following resources are helpful for the oral presentation and written paper of the student project.

Scientific writing

- http://abacus.bates.edu/~ganderso/biology/resources/writing/HTWtoc.html
  → Very helpful resource. The only thing that is missing is how to write the conclusions section. Note that the conclusion section is required in the student project – but not in some journals.
- Wallwork, A. (2016) English for Writing Research Papers, 2nd ed. 2016, Cham: Springer International Publishing (Online Version available via http://www.library.ethz.ch/en/).
  → I especially like the sections on how to learn from other papers (Section 1.4: How can I know exactly what the editor is looking for? and Section 1.6 How can I create a template?), to systematically identify what the editor and reviewers are looking for, how to approach developing the structure of your paper, and the focus on key findings.
- Lebrun, J.-L. (2011) Scientific writing 2.0 a reader and writer's guide, World Scientific, New Jersey.
  → The book is also available at ETH/Eawag as PDF directly at the publisher: http://www.worldscientific.com/worldscibooks/10.1142/8156#t=toc

Oral presentations

- Alley, M. (2013) The craft of scientific presentations - Critical steps to succeed and critical errors to avoid, 2nd, Springer, New York.
  http://www.craftofscientificpresentations.com/
  http://link.springer.com/book/10.1007%2F978-1-4419-8279-7
  → Oral presentations must be organized different from a written report or a scientific paper. This book (available as PDF from the ETH library and the videos at http://www.craftofscientificpresentations.com/ provide an excellent introduction into how to approach an interesting and successful presentation.
- Lutz, H., Heike, H. and Klaus-Geert, H. (2009) Technische Berichte: verständlich gliedern, gut gestalten, überzeugend vortragen, Wiesbaden : Vieweg + Teubner.
  → PDF of book available online at ETH library. A comprehensive guide to writing reports and oral presentations (in German).

Credit conditions (3 ECTS credits):

Grading

Grades will be assigned based on the oral presentation (25%), written report (60%), and the practical work during the project (15%).

The grade for oral presentation, written report, and practical work for the overall team will be adjusted for individual team members based on individual effort assessments. More details to the evaluation will be provided by the beginning of the second half of the semester.

Program:

N°.	Date	Room	Topic	Purpose / Comments	Deliverables
	28.09.16				Students submit "questionnaire on background and availability"
	05.10.16		Assignment of student teams by the instructor		
	12.10.16				Teams submit proposal for two possible project topics
	19.10.16		Teams are assigned a specific topic		
1	07.11.16	HCI D8	Student presentations of research topic, specific research question, and outlook on how to approach answering the question	Formulate specific questions and get some initial feedback from other students and instructors	Oral presentation of the **specific research question** to the entire class
2	09.11.16	HIL E8	CASE STUDY:	The CASE STUDY can be considered as a reduced version of the larger STUDENT PROJECT.	
3	14.11.16	HCI D8	CASE STUDY (Cont'd)		
4	16.11.16	HCP	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	
5	21.11.16	HCI	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	
6	23.11.16	HCP	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	Submit written **draft of introduction, materials and methods,** and initial results as basis for peer review and feedback from instructor/teaching assistant
7	28.11.16	HCI	Meetings with peer review partners and instructor/teaching assistant	You will have multiple benefits from this peer review meeting: You get feedback not only from the instructor/teaching assistant but also from other teams. And you have the additional benefit from critically reviewing another project. Critically reviewing another project and discussing with another team is often very helpful also for your own work.	Prepare **peer review** of assigned other teams and discuss with other teams during meeting.

N°.	Date	Room	Topic	Purpose / Comments	Deliverables
8	30.11.16	HIL E8	Lecture: Your treatment plant does now work – what could limit treatment plant performance? Linking process stoichiometry, kinetics, availability of microorganisms, and mass transport limitations	In your STUDENT PROJECT, as a scientist, or as a consulting engineer one of the most difficult questions is to identify the most sensitive process influencing process performance. During this meeting we will discuss general approaches to evaluate what processes are the most relevant to consider during your research or when fixing a treatment plant. Students will benefit from the structured evaluation of process limitations for their student projects.	
9	05.12.16	HCI	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	
10	07.12.16	HCP	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	Submit written **draft of results and conclusions**
11	12.12.16	HCI	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	
12	14.12.16	HCP	Instructor/teaching assistant are available for individual feedback	Meeting times for groups will be assigned.	
13	19.12.16	HCI D8	STUDENT PROJECT (Term Paper): Final presentation		Oral presentation to the entire class
14	21.12.16	HIL E8	STUDENT PROJECT (Term Paper): Final presentation (Cont'd)		Oral presentation to the entire class
	23.12.16				Submission of f**inal version of research paper** on last day of the semester

APPENDIX: List of suggested themes and specific topics for the student projects

[NOTE: The citation of journal articles in the section below is still incomplete. An updated version will be made available during the semester.]

Advanced microbial processes

Concept: What novel microbial process have you learned about (lectures, journal articles, …) that goes beyond ASM 1/2/3? How would you approach developing a suitable mathematical model for this process? Do you have sufficient information to justify this modeling approach? What data can you use to support the validity of your suggested approach?

1. Develop, calibrate, and apply an extended version of ASM3 based on understanding of basic microbial processes (e.g., two-step nitrification, EBPR, GAO metabolism, N_2O production) (Chandran and Smets, 2005, Kaelin et al., 2009, Lopez-Vazquez et al., 2009). Implement the model and compare model predictions with basic ASM3 predictions and/or experimental data.
2. ASM3 assumes only one group of heterotrophic bacteria (X_H) and one type of nitrifier (X_A). What would be the effect if there would be a range of X_H and X_A with variable kinetic parameters on process performance?
3. Relevance of the sulfur cycle in activated sludge treatment systems (Wu et al., 2014)

Process evaluation

Concept: Can you use a mathematical model to evaluate complex treatment processes in existing systems? What information do you have on the real life processes? Do you have sufficient understanding to use the mathematical model to advance your understanding?

4. Evaluate the influence of inhomogeneous mixing conditions (i.e., short circuiting or dead zones or variable flow conditions) on process performance using a mathematical model. Critically evaluate your results.
5. Evaluate the potential for biological processes in sewers to achieve significant treatment during the conveyance of wastewater.
6. Compare the influence of process conditions in a membrane bioreactor (MBR) with a conventional activated sludge tank. How are sludge flocs different in MBRs compared to conventional activated sludge and how does this influence system performance?
7. The influence of nitrification and CO_2 stripping on pH during the operation of a sequencing batch reactor treated concentrated wastewater (Serralta et al., 2004, Flores-Alsina et al., 2015, Fumasoli et al., 2016).
8. Find a journal publication that provides experimental or full-scale data and/or that presents a mathematical model for biological processes. Implement a mathematical model for the system in SUMO and critically discuss the journal paper based on your own simulations.
9. Students design activated sludge treatment plant for unusual influent conditions.
10. Students use mathematical modeling to evaluate critical loading and operating conditions for a treatment plant with strong variability of influent loading or influent composition. Large variations in loading are typical, for example, for decentralized treatment plants. Students can do a preliminary design for a treatment plant and use the mathematical modeling to test different loading scenarios.

Design thinking

Concept: Use existing mathematical models to support your evaluation of a novel process idea.

11. Identify a novel approach for a treatment process. What is the treatment objective? How would you approach design? How would you use modeling in SUMO to test the suggested process?
12. Evaluate the Dephanox process (Bortone, G., Saltarelli, R., Alonso, V., Sorm, R., Wanner, J. and Tilche, A. (1996) Biological anoxic phosphorus removal - The dephanox process. Water Science and Technology 34(1-2), 119-128) using hand calculations and mathematical modeling. What parts of the process do you need to model in more or less detail? What influences the decision on where to put emphasis in your modeling? What can you learn from your modeling and what are the uncertainties?

Student defined project

Concept: The project must include mathematical modeling of biological processes and it must include a critical evaluation of modeling results.

References

Chandran, K. and Smets, B.F. (2005) Optimizing experimental design to estimate ammonia and nitrite oxidation biokinetic parameters from batch respirograms. *Water Research* 39(20), 4969-4978.

Flores-Alsina, X., Mbamba, C.K., Solon, K., Vrecko, D., Tait, S., Batstone, D.J., Jeppsson, U. and Gernaey, K.V. (2015) A plant-wide aqueous phase chemistry module describing pH variations and ion speciation/pairing in wastewater treatment process models. *Water Research* 85, 255-265.

Fumasoli, A., Etter, B., Sterkele, B., Morgenroth, E. and Udert, K.M. (2016) Operating a pilot-scale nitrification/distillation plant for complete nutrient recovery from urine. *Water Sci Technol* 73(1), 215-222.

Hubaux, N., Wells, G. and Morgenroth, E. (2015) Impact of coexistence of flocs and biofilm on performance of combined nitritation-anammox granular sludge reactors. *Water Research* 68, 127-139.

Kaelin, D., Manser, R., Rieger, L., Eugster, J., Rottermann, K. and Siegrist, H. (2009) Extension of ASM3 for two-step nitrification and denitrification and its calibration and validation with batch tests and pilot scale data. *Water Research* 43(6), 1680-1692.

Lopez-Vazquez, C.M., Hooijmans, C.M., Brdjanovic, D., Gijzen, H.J. and van Loosdrecht, M.C.M. (2009) Temperature effects on glycogen accumulating organisms. *Water Research* 43(11), 2852-2864.

Morgenroth, E. and Wilderer, P.A. (2000) Influence of detachment mechanisms on competition in biofilms. *Water Research* 34(2), 417-426.

Oakley, B., Felder, R.M., Brent, R. and Elhajj, I. (2004) Turning student groups into effective teams. *Journal of student centered learning* 2(1), 9-34.

Serralta, J., Ferrer, J., Borras, L. and Seco, A. (2004) An extension of ASM2d including pH calculation. *Water Research* 38(19), 4029-4038.

Wu, D., Ekama, G.A., Wang, H.G., Wei, L., Lu, H., Chui, H.K., Liu, W.T., Brdjanovic, D., van Loosdrecht, M.C.M. and Chen, G.H. (2014) Simultaneous nitrogen and phosphorus removal in the sulfur cycle-associated Enhanced Biological Phosphorus Removal (EBPR) process. *Water Research* 49, 251-264.