# Study guide for the oral exam

**Learning objectives**

The final exam will be comprehensive and cover the material of the entire first half of the semester. The material covered includes the content of the lectures, material handed out during class, assigned reading, and information from the homework assignments. The following list of learning objectives should guide you in studying for this course (note that this list is meant to highlight important topics but is not necessarily comprehensive):

- List important parameters used to characterize wastewater and calculate expected values for a given chemical (e.g., COD or TOD based on chemical composition).
- Metabolism: Calculate energy released in catabolic reactions and energy required in anabolic reactions and describe different microbial processes in terms of energy source, carbon source, and electron donor and acceptor.
- Stoichiometry: Predict the maximum yield ($f_s$ or Y) based on energy calculations for the metabolism. Convert the yield to appropriate units (e.g., g VSS/g COD or g VSS/g N or g COD/g COD,...) and calculate the net yield taking into account decay and production of inert biomass.
- Write overall stoichiometric reaction based on the estimated growth yield.
- Develop the matrix notation of complex microbial processes based on information on kinetics, stoichiometry, and conservation principles.
- Design a CSTR with biomass growth and decay and evaluate the influence of hydrolysis of particulate organic matter, influent inert biomass, and inhibition. Develop relevant mass balances based on different types of process kinetics, stoichiometry and determine effluent substrate and nutrient and electron acceptor demand. For selected cases solve these mass balances.
- Design an activated sludge treatment plant for BOD removal based on preparing and solving appropriate mass balance(s) for aeration tanks, settler, or overall system. Design information includes volume of reactor, biomass concentrations in different reactors, required oxygen input, nutrient requirements, and amount of sludge wastage.
- Design activated sludge treatment plants for nitrification, nitrogen removal, and biological phosphorus removal. As part of the design, estimate stoichiometric relationships between electron donors (e.g., BOD, $H_2$, ...) and electron acceptors (e.g., nitrate, nitrite, ...), perform kinetic calculations, and evaluate different process schematics in terms of their suitability for efficient nutrient removal.
- Explain the relevance of the solids retention time (SRT) in activated sludge systems, derive the SRT for different types of systems, discuss the relevance of the aerobic SRT, and use SRT as basis for the design.
- Discuss the sensitivity of system performance on wastewater characteristics, kinetic/stoichiometric parameters and reactor operation. Evaluate the influence of variable loading on system performance.
- Discuss the motivations for choosing different reactor configurations. Explain the background and criteria for choosing different safety factors.
- Calculate substrate concentrations inside a biofilm, flux of substrate into the biofilm, and overall biofilm reactor performance using analytical solutions (e.g. for 1st or 0-order reaction rates) or concentration profiles provided from measurements/numerical simulations.
- Design a biofilm reactor based on an overall mass balance for the biofilm reactor.
- Evaluate competition between different organisms in activated sludge and biofilm systems. The competitive advantage can be linked to factors such as preferential access to electron donor/electron acceptors, kinetic/stoichiometric parameters, or metabolic capabilities (e.g., ability of an organism to store substrates).
- Evaluate how the anaerobic food web will affect reactor operation in terms of volatile fatty acids, pH, and alkalinity and describe the role of different microbial populations in the overall anaerobic digestion process.
- Perform stoichiometric calculations for anaerobic digestion to estimate gas production and gas composition and estimate the thermodynamic feasibility of individual catabolic processes depending on substrate and product concentrations.

One good way to study for the exam is to do the assigned homework problems and work through examples and problems in our textbook - in the past I have always prepared some exam questions based on examples/problems taken from the book. And note that we will have an oral exam. During the oral exam I expect that you are able derive and solve equations and justify your answers based on first principles.