Coordinating unit: 250 - ETSECCPB - Barcelona School of Civil Engineering  
Teaching unit: 745 - EAB - Department of Agri-Food Engineering and Biotechnology  
Academic year: 2015  
Degree: MASTER'S DEGREE IN ENVIRONMENTAL ENGINEERING (Syllabus 2014). (Teaching unit Compulsory)  
ECTS credits: 5  
Teaching languages: Catalan, Spanish, English

Coordinating unit: XAVIER FLOTATS RIPOLL  
Others: XAVIER FLOTATS RIPOLL

Opening hours

Timetable: To be arranged; preferably after teaching hours.

Teaching methodology

The course consists of 3 hours per week of classroom activity (large size group).

About 1.5 hours average in the large size groups are devoted to theoretical lectures, in which the teacher presents the basic concepts and topics of the subject, shows examples and solves exercises.

About 1.5 hours average in the large size group is devoted to solving practical problems with greater interaction with the students. The objective of these practical exercises is to consolidate the general and specific learning objectives. Some strategies for solving the proposed problems, to be solved by students, will be discussed also.

Support material in the form of a detailed teaching plan is provided using the virtual campus ATENEA: content, written documentation prepared by the professor, collection of solved problems, collection of proposed problems to be solved, codes of simulation programs to be used as templates and assessment activities conducted.

Learning objectives of the subject

CE01 - Apply scientific concepts to environmental problems and their correlation with technological concepts.  
CE02 - Analyze systems, environmental problems and their resolution using models and evaluate them.  
CE03 - Acquire basic skills of laboratory work and identify the methods and instrumentation for the determination of parameters relevant to the analysis of environmental problems.

Very aware of the structure of land, water and artificial ecosystems and their interactions.  
Meet the ecology and the cycling of elements.  
Meet the major environmental problems globally.  
Analyzes energy bases, stoichiometric and kinetic of different processes.  
Modeling process and quantifies the performance and efficiency of systems.  
Determines the basis of environmental hazards to human health and ecosystems.  
Apply material balances and energy to environmental problems.  
Interprets water-rock and water - air interactions using thermodynamic and kinetic methods.  
Meet the pollutants and identify their impact.
Learn the basics of how the atmosphere and applies them in maintaining air quality.
Learn the basics of climate and discusses the implications of current climate change.
Conceptualized an environmental problem described by equations and poses analytical or numerical solution.
Identifies the codes you need to solve a problem as conceptualized.
Recognizes the spatial and temporal scales required to resolve the problem.
Is familiar with solutions to problems relating to dynamical systems.
Learn about simple solutions to problems advection-dispersion-reaction.
Recognizes the existence of uncertainty in the parameters of the equations and is capable of performing an uncertainty analysis and sensitivity.
Learn methods for information and action on various parameters or variables.
Understand that any measure inherently carries an associated error and is able to work with them.
It is critical to the values reported by others when the measurement method is not specified.
He has worked in the laboratory measurement of some parameters of environmental interest.

Dynamic processes, reactions and reactors.
Bioenergetics and stoichiometry of biological reactions.
Kinetics of biological processes of interest in environmental engineering.
Kinetics of biofilm reactors and immobilized biomass.
Simultaneous expression of matrix kinetic biological processes.
Technical parameter identification of biological processes.
Techniques of qualitative and quantitative measurement of microbial populations.

The specific objective of the course is to build a solid foundation of knowledge and skills to further deal with the design and operation of biological processes with environmental engineering interest.

### Study load

<table>
<thead>
<tr>
<th>Total learning time: 125h</th>
<th>Theory classes: 15h</th>
<th>12.00%</th>
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</thead>
<tbody>
<tr>
<td></td>
<td>Practical classes: 10h</td>
<td>8.00%</td>
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<tr>
<td></td>
<td>Laboratory classes: 10h</td>
<td>8.00%</td>
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<td></td>
<td>Guided activities: 10h</td>
<td>8.00%</td>
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<tr>
<td></td>
<td>Self study: 80h</td>
<td>64.00%</td>
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</table>
# Content

## Processes dynamics, reactions and reactors

<table>
<thead>
<tr>
<th>Description:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport and reaction processes</td>
</tr>
<tr>
<td>Equations of the mass balance</td>
</tr>
<tr>
<td>Transport by diffusion and convection</td>
</tr>
<tr>
<td>The continuity equation</td>
</tr>
<tr>
<td>Homogeneous and heterogeneous reactions</td>
</tr>
<tr>
<td>Orders of reaction. Kinetic data</td>
</tr>
<tr>
<td>Applications of first order reaction</td>
</tr>
<tr>
<td>Enzymatic reactions. Michaelis-Menten kinetics</td>
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<tr>
<td>Monod kinetics</td>
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<tr>
<td>Associated physical and chemical processes: chemical equilibria and gas-liquid transfer</td>
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</table>

<table>
<thead>
<tr>
<th>Learning time: 9h 36m</th>
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<tbody>
<tr>
<td>Theory classes: 3h</td>
</tr>
<tr>
<td>Practical classes: 1h</td>
</tr>
<tr>
<td>Self study: 5h 36m</td>
</tr>
</tbody>
</table>

- Completely mixed batch reactor
- Completely mixed continuous reactor
- Completely mixed continuous reactor with biomass recirculation
- Ideal plug flow continuous reactor
- Problems and exercises of the topic

## Bioenergetics and stoichiometry of biological reactions

<table>
<thead>
<tr>
<th>Description:</th>
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<tbody>
<tr>
<td>Classification of microorganisms</td>
</tr>
<tr>
<td>Structure and components of the cell.</td>
</tr>
<tr>
<td>Functions and features of bacteria.</td>
</tr>
<tr>
<td>Nutritional requirements for growth.</td>
</tr>
<tr>
<td>Sources of carbon and energy. Microbial diversity.</td>
</tr>
<tr>
<td>Qualitative and quantitative techniques for measuring microorganisms populations</td>
</tr>
<tr>
<td>Stoichiometric equations.</td>
</tr>
<tr>
<td>Anabolism and catabolism. Energy and growth</td>
</tr>
<tr>
<td>Partition of substrate and cells production</td>
</tr>
<tr>
<td>Coefficients of biomass production, energy and free energy of the biological reaction.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Learning time: 16h 48m</th>
</tr>
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<tbody>
<tr>
<td>Theory classes: 4h</td>
</tr>
<tr>
<td>Practical classes: 3h</td>
</tr>
<tr>
<td>Self study: 9h 48m</td>
</tr>
</tbody>
</table>

- Problems and exercises of the topic
### Kinetics of biological processes in environmental engineering interest

**Learning time:** 12h
- Theory classes: 3h
- Practical classes: 2h
- Self study: 7h

**Description:**
- Growth rate and decay
- Effect of toxics and inhibitors
- Effect of temperature
- Effect of pH
- Transformation of substrate into biomass. Stoichiometric coefficients

- Hydrolysis. First order and Contois kinetics
- Decay kinetics
- Growth of heterotrophic biomass in aerobic environment. Nitrification.
- Growth of autotrophic biomass in aerobic environment. Denitrification.
- Concepts of Anammox process (ammonia oxidation in anoxic environment). Heterotrophic and autotrophic growth of biomass in anaerobic environment
- Growth of phosphorous accumulating microorganisms (PAO)
- Growth of sulfate reducing microorganisms

- Problems and exercises of the topic

### Simultaneous biological processes

**Learning time:** 9h 36m
- Theory classes: 2h
- Laboratory classes: 2h
- Self study: 5h 36m

**Description:**
- Simultaneous biological processes. Matrix notation
- Petersen matrix
- Obtaining the set of equations of the system

- The ASM models of the International Water Association (IWA)
- IWA- ADM1 model
- Three-phase models for the composting process

- Problems and exercises of the topic
## Kinetics of biofilms and immobilized biomass reactors

**Description:**
- Biofilms and aggregates. Definition and characteristics
- Biofilm kinetics
- Analytical solutions for zero and first-order kinetics
- Effect of the external transport resistance
- Mass balance equations for biofilm reactors
- Obtaining the solutions of the continuity equation for different kinetics
- Application to CSTR and plug flow reactors
- Biofilm penetration and limiting substrate
- Effect of effluent recirculation
- Problems and exercises of the topic

**Learning time:** 12h  
- Theory classes: 3h
- Practical classes: 2h
- Self study: 7h

## Case studies

**Description:**
- Suspended biomass systems
- Attached and immobilized biomass systems
- Systems for liquid, solid, gaseous or heterogeneous media
- Combination of processes based on objectives
- Oxidation of organic matter and ammonia
- Oxygen transfer
- Processes in anaerobic media
- Anaerobic digestion and methane production
- Combination aerobic - anoxic
- Combination anaerobic - anoxic - aerobic

**Learning time:** 19h 12m  
- Theory classes: 2h
- Laboratory classes: 6h
- Self study: 11h 12m
### Identification of parameters

<table>
<thead>
<tr>
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<tbody>
<tr>
<td>Need for identifying model parameters</td>
</tr>
<tr>
<td>Observable and identifiable systems</td>
</tr>
<tr>
<td>Application of the method of Taylor series expansion</td>
</tr>
</tbody>
</table>

| Calculation of FIM (Fisher Information Matrix) |
| Experimental design for practical identification |
| Statistical characterization of estimated parameters |

**Problems and exercises of the topic**

### Evaluation of the course

<table>
<thead>
<tr>
<th>Learning time: 9h 36m</th>
</tr>
</thead>
<tbody>
<tr>
<td>Theory classes: 2h</td>
</tr>
<tr>
<td>Practical classes: 2h</td>
</tr>
<tr>
<td>Self study: 5h 36m</td>
</tr>
</tbody>
</table>

### Qualification system

The mark of the course will be obtained from the rating of the solved exercises and problems collection, the activity of numerical simulation and the rating of the final exam. The weighting for qualifying students is as follows:

- Theory part of the exam: 30%
- Problems part of the exam: 25%
- Solved exercises collection: 35%
- Activity of numerical simulation: 10%

The students with a final mark between 4 and 5 could go to a re-evaluation exam. In case of pass it, the student will obtain a final mark of 5.

### Regulations for carrying out activities

The collection of solved exercises and the report of the numerical simulation of complex biological processes can be done individually or in groups of a maximum of 3 people. The delivery deadline is the last day of class before the final exam. The theoretical part of the examination will consist of written answers on conceptual questions and the student may not consult any documentation.

The problem part of the exam will consist of a written resolution of one or two problems or exercises. Students will have the calculator and could consult the documentation they desire individually. They could also consult information on digital support individually.

### Bibliography

- Identification of parameters
- Evaluation of the course
- Qualification system
- Regulations for carrying out activities
- Bibliography