2EL2040 – Chemical Engineering: application to environment and sustainable production

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Department: DÉPARTEMENT MÉCANIQUE ENERGÉTIQUE PROCÉDÉS
Language of instruction: ANGLAIS
Campus: CAMPUS DE PARIS - SACLAY, CAMPUS DE METZ
Workload (HEE): 60
On-site hours (HPE): 35,00
Elective Category : Engineering Sciences
Advanced level : No

Description

Process Engineering consists in designing, operating and optimizing processes for the development of various products and services in many traditional and high-tech sectors (agri-food, biotechnology, cosmetics, fine chemicals, materials, oil, pharmaceuticals, water and waste treatment, etc.) and for the production of traditional, low-carbon and renewable energies.
This course is an introduction to Process and Bioprocess Engineering and its methodologies. The fundamentals of the course allow students to acquire general tools that can be easily transposed to multiple fields.

The sustainability of processes is a major challenge.
Some processes are intrinsically key tools in the global sustainable development strategy at different scales (local and global), such as the recycling and recovery of many products and the purification of liquid and gaseous effluents.
Nevertheless, in general, new processes must be developed and existing processes must be optimized (intensification) in order to reduce the impacts of the industrial sector. The challenges associated with this environmental dynamic are multiple: reduction of energy and raw material consumption, costs, waste, risks and dangers.
In addition, bioprocesses have developed very strongly in the last decades for two reasons: (i) the use of living organisms, acting as processing plants, to transform matter, purify polluted systems (liquid, solid), (ii) the use of biomass to replace fossil resources.

This course is based on concrete examples (simplified in order to make them intelligible), allowing students to apply and learn the fundamentals of the course, while focusing on processes oriented towards sustainable development.
Some case studies are focused on bioprocesses used in industrial and environmental biotechnology. Bioprocesses are studied at the industrial bioreactor scale. The description and understanding of biological processes

(metabolism, maintenance, etc.) at the cell level are not addressed. The biological agents are thus considered as cellular catalysts transforming raw materials into products according to given kinetic laws whose application does not need any specific background in biology.

Quarter number
SG8

Prerequisites (in terms of CS courses)
None

Syllabus

1. Introduction to Process Engineering for Sustainable Development; steady state material balance
<u>Case study:</u> Process for the production of 1st generation bioethanol (*conversion of renewable raw materials by white biotechnologies*)

2. Flow models (perfectly agitated and plug flow)
<u>Case study:</u>
Valorization of Whey (*Valorization of residues from the food industry by white biotechnology*)
Dimensioning of biological treatment tank basin of an urban wastewater treatment plant (*process in the service of the environment, reduction of reactor volumes and groundwater footprint*)

3. Thermal balances: calorific / enthalpic
<u>Case study:</u> Dimensioning of a backer yeast production reactor in batch mode (*optimisation of the reactor geometry and its thermal regulation*)

4. Liquid-vapor balances equilibria, single and multi-stage distillation
<u>Case study:</u> Flash distillation flash of ethanol/water mixture ; Multistage distillation of bioethanol (*alternative to fossil fuels*)

5. Mass Transfer: Diffusion & Convection
<u>Case study:</u> Production in raceway of Spirulina Mocroalgae (*sustainable production of nutrient for food and feed*)

6. Mass Transfer: Permanent Contact Technologies
<u>Case study:</u>
Treatment of a gaseous effluent. Removal of a pollutant (*environmental process*)
Biogas purification for biomethane production by membrane technology (*production of a renewable energy carrier for conventional uses*)

Class components (lecture, labs, etc.)

The course module is organized in lectures (16.5h), to introduce knowledge and methodological tools, which will be then applied through case studies (16.5h). The pedagogical mode of the lectures (face-to-face or flipped classroom) will be decided collectively during the first lesson. The case studies will be conducted in class. The students will be in groups and will produce a report to be submitted at the end of each lesson. Two of the case studies will consist of mini-projects to be carried out by groups in autonomy during 3 hours.

Grading

Homework: Presentation, by group, of a litterature survey whose topic is an extension of the course (40% of the grade); this presentation may take place either by an oral session of by a poster session take place .Individual final written exam: 2-hour case study (60% of the grade).

Course support, bibliography

- **Slideshows**

• **Techniques de l'ingénieur :**
+ Charpentier J., Génie des procédés, développement durable et innovation – Enjeux et perspectives, 2013
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière – Méthodologie, 2000
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Isambert A., Transfert de matière – Distillation compartimentée idéale, 2001
+ Moulin J.P., Pareau D., Rakib M., Stambouli M., Transfert de matière- Autres opérations compartimentées, 2002
+ Buch A., Rakib M., Stambouli M., Transfert de matière- Cinétique du transfert de matière entre deux phases, 2008
+ Sun L.M., Thonnelier J.Y., Perméation gazeuse, 2004
+ Vuillermaux J., Réacteurs chimiques – Principes, 1994
+ Boulinguiez B., Le Cloirec P., Purification de biogaz – Élimination des COV et des siloxanes, 2011

• **General Books:** Perry Chemical Engineer's Handbook, 8th edition, 2007, McGraw-Hill, New York

• **Specific books:**
- *Reactor and bioreactor engineering*
+ Coulson and Richardson's Chemical Engineering – Volume 3A: Chemical and Biochemical Reactors and Reaction Engineering, 4th Edition, 2017, Elsevier. Oxford
+ Fogler H.S., Elements of chemical reaction engineering, 5th Edition, 2016, Pearson Education, Englewood Cliffs
+ Levenspiel O., Chemical Reaction Engineering, 3rd edition, 1999, John Wiley and Sons, New York
+ Villadsen J., Nielsen J., Lidén G., Bioreaction Engineering Principles, 3rd Edition, 2011, Springer, New York

- *Heat and mass transfer*
+ Bergman T.L., Lavine A.S., Incropera F.P., Dewitt F., Fundamentals of Heat and Mass Transfer, 7th Edition, 2011, John Wiley and Sons, New York
+ Coulson and Richardson's Chemical Engineering – Volume 1B: Heat and Mass Transfer: Fundamentals and Application, 7th Edition, 2018, Elsevier, Oxford
+ Cussler E.L., Diffusion Mass Transfer in Fluid systems, 3rd Edition, 2009, Cambridge University Press, Cambridge
+ Treybal R., Mass Transfer Operations, 4th Edition, 1982, McGraw Hill, New York
- *Bioethanol production*
+ Cardona C.A., Sanchez O.J., Gutierrez L.F, Process synthesis for fuel ethanol production, 2010, CRC Press, Boca Raton
+ Naik S.N., Goud V.V., Rout P.K., Dalai A.K, Production of first and second generation biofuels: A comprehensive review, Renewable and Sustainable Energy Reviews 14, 2010, 578–597
+ Vohra M., Manwar J., Manmode R., Padgilwar S., Patil S. Bioethanol production: Feedstock and current technologies, Journal of Environmental Chemical Engineering 2, 2014, 573–584

Resources

Teaching staff (instructor(s) names):Francois PUEL / Victor POZZOBON / Cristian PUENTES
Maximum enrolment (default 35 students): 60
Software, number of licenses required: Excel, Python
Equipment-specific classrooms (specify the department and room capacity): None

Learning outcomes covered on the course

At the end of this course, students will be able to:

- List the type of mass transfer and its coupling to heat transfer,
- Identify the different mass transfer mechanisms (diffusion / convection) working in a given configuration and the potential coupling between heat and mass transfer,
- Write mass balances, taking into account, if necessary, chemical or biochemical reaction kinetics,
- Simplify a seemingly complicated problem, where several transfer phenomena coexist, by taking into account only the main ones,
- Formalize phenomena into equations through elemental balances,
- Design conversion and separation technologies based on thermodynamic and kinetic considerations.

Description of the skills acquired at the end of the course

- C1.1. : Examine problems in their entirety and beyond their immediate parameters. Identify, formulate and analyse the scientific, economic and human dimensions of a problem **Milestone 1**
- C1.2. : Develop and use appropriate models, choosing the correct modelling scale and simplifying assumptions when addressing a problem **Milestone 1**
- C1.3. : Solve problems using approximation, simulation and experimentation **Milestone 1B**
- C7.1. : Persuade at core value level; to be clear about objectives and expected results. To apply rigour when it comes to assumptions and structured undertakings, and in doing so structure and problematise the ideas themselves. Highlight the added value **Milestone 1**