الجمهورية الجزائرية الديمقراطية الشعبية République Algérienne Démocratique et Populaire
وزارة التعليم العالي والبحث العلمي
Ministère de l'Enseignement Supérieur et de la Recherche Scientifique
اللجنة البيداغوجية الوطنية لميدان العلوم و التكنولوجيا
Comité Pédagogique National du domaine Sciences et Technologies

MASTER ACADEMIQUE HARMONISE

Programme National

2025 Update

Field	Branch	Major
Science and Technology	***Process Engineering***	***Environmental Process Engineering***

I – Master's Program Information

Admission Requirements

Branch	**Harmonized Master**	**Bachelor's Degrees Eligible for Master**	Ranking according to license compatibility	Coefficient Assigned to the License
Process Engineeri	Environmental Process Engineering	Process Engineering	**1**	**1.00**
		Materials Engineering	**2**	**0.80**
		Materials Chemistry (Science & Technology Field)	**3**	**0.70**
		Materials Physics (Science & Technology Field)	**3**	**0.70**
		Inorganic Chemistry (Science & Technology Field)	**4**	**0.65**
		Other Bachelor's Degrees in Science & Technology	**5**	**0.60**

II – II – Semester Structure of the Specialization

Semester 1: Environmental Process Engineering

Teaching Unit	Subjects	Credits	Coefficient	Weekly Hours			Semester Hours (15 weeks)	Additional Work (Consultation, 15 weeks)	Assessment Method –/ Exam	
	Title			Lecture	Tutorial	Lab			Continuous Assessment	Exam
Fundamental UE Code: UEF 1.1.1 Credits: 8 Coefficient: 4	Water Chemistry	4	2	1h30	1h30		45h00	55h00	40%	60%
	Atmospheric Pollution	4	2	1h30	1h30		45h00	55h00	40%	60%
Fundamental UE Code : UEF 1.1.2 Credits : 10 Coefficients : 5	Unit Operations Fluid-Fluid (Extraction, Distillation, Absorption, Stripping)	6	3	3h00	1h30		67h30	82h30	40%	60%
	Heat Exchangers	4	2	1h30	1h30		45h00	55h00	40%	60%
Methodological UECode : UEM 1.1 Credits : 11 Coefficients : 7	Lab – Water Chemistry	2	1			1h30	22h30	27h30	100%	
	Lab – Unit Operations (Fluid-Fluid)	2	1			1h30	22h30	27h30	100%	
	Lab – Heat Exchangers	2	1			1h30	22h30	27h30	100%	
	Process Engineering Simulators	3	2	1h30		1h00	37h30	37h30	40%	60%
	Advanced Python Programming	2	2	1h30		1h30	45h00	55h00	40%	60%
Discovery UE Code : UED 1.1 Credits : 1 coef : 1	Optional Course	1	1	1h30			22h30	2h30		100%
Total Semester 1		**30**	**17**	**12h00**	**6h00**	**7h00**	**375h00**			

Semestre 2 : Environmental Process Engineering

Teaching Unit	Subjects	Credits	Coefficient	Weekly Hours			Semester Hours (15 weeks)	Additional Work (Consultation, 15 weeks)	**Assessment Method –/ Exam**	
	Title			**Lecture**	**Tutorial**	**Lab**			Continuous Assessment	**Examen**
Fundamental UE Code : UEF 1.2.1 Credits : 10 Coefficients : 5	Drinking Water Production	6	3	3h00	1h30		67h30	82h30	40%	60%
	Solid Waste Management and Treatment	4	2	1h30	1h30		45h00	55h00	40%	60%
Fundamental UE Code : UEF 1.2.2 Crédits : 8 Coefficients : 4	Adsorption Processes and Membrane Separation	4	2	1h30	1h30		45h00	55h00	40%	60%
	Physico-Chemical Treatment of Wastewater	4	2	1h30	1h30		45h00	55h00	40%	60%
Methodological UE Code : UEM 1.2 Crédits : 9 Coefficients : 5	Porous and Dispersed Media	3	2	1h30	1h00		37h30	37h30	40%	60%
	Lab – Water Treatment & Adsorption / Membrane Separation	2	1			1h30	22h30	27h30	100%	
	Water Treatment and Process Conditioning	4	2	1h30	1h30		45h00	55h00	40%	60%
Transversal UE Code : UET 1.2 Crédits : 3 coefficient : 3	Ethics, Standards, and Integrity	1	1	1h30			22h30	2h30		100%
	Applied AI Elements	1	1	1h30	1h30		45h00	5h00	40%	60%
Total semestre 2		**30**	**17**	**15h00**	**8h30**	**1h30**	**375h00**	**375h00**		

Semestre 3 : Environmental Process Engineering

Teaching Unit	Subjects – Title	Credits	Coefficient	Weekly Hours – Lecture	Weekly Hours – Tutorial	Weekly Hours – Lab	Semester Hours (15 weeks)	Additional Work (Consultation, 15 weeks)	Assessment Method –/ Exam – Title	Assessment Method –/ Exam – Examen
Fundamental UECode : UEF 2.1.1 Crédits : 8 Coefficients : 4	Theoretical Fundamentals and Biological Wastewater Treatment	4	2	1h30	1h30		45h00	55h00	40%	60%
	Gaseous Effluent Treatment	4	2	1h30	1h30		45h00	55h00	40%	60%
Fundamental UECode : UEF 2.1.2 Crédits : 10 Coefficients : 5	Technical Thermodynamics	4	2	1h30	1h30		45h00	55h00	40%	60%
	Multiphase Reactors and Bioreactors	6	3	3h00	1h30		67h30	82h30	40%	60%
Methodological UE Code : UEM 2.1 Crédits : 9 Coefficients : 5	Lab – Biological Wastewater Treatment / Bioreactors	2	1			1h30	22h30	27h30	100%	
	Process Intensification	2	1	1h30			22h30	27h30		100%
	Polluted Soil Treatment	2	1	1h30			22h30	27h30		100%
	Experimental Design	3	2	1h30		1h00	37h30	37h30	40%	60%
Transversal UE Code : UET 2.1 Crédits : 3, coef. 3	Chemical reserve engineering Workshop	2	2	1h30	1h30 Workshop		45h00	5h00	40%	60%
	Literature Research and Thesis Design	1	1	1h30			22h30	2h30		100%
Total semestre 3		**30**	**17**	**15h00**	**6h00**	**4h00**	**375h00**	**375h00**		

General Guidelines for Choosing Optional / Discovery Courses:

1. Technical and Economic Evaluation of Processes
2. Environmental Management
3. Environmental Audit and Impact Assessment
4. Ecology and Biodiversity
5. Renewable Energy
6. Industrial Risks and Natural Disasters
7. Chemical and Biochemical Sensors
8. Climate Change
9. Environmental Changes and Biological Invasions
10. Biofuel Cells
11. Sonochemistry
12. Activation Processes
13. Energy Storage
14. Biomass and Biofuels
15. Environmental Standards and Conventions
16. Process Control and Regulation
17. Process Modeling and Optimization
18. Environmental Microbiology and Biochemistr

Semestre 4

Internship in a company or a research laboratory, concluded with a dissertation and an oral defense .

	VHS	Coeff	Credits
Personal Work	550	09	18
Internship in Industry or Research Laboratory	100	04	06
Seminars	50	02	03
Other Supervision / Mentoring	50	02	03
Total Semestre 4	750	17	30

This table is provided for guidance only

Evaluation of the Master's Final Project

- **Scientific Value** (Assessment by the Jury) /6
- **Thesis Writing** (Assessment by the Jury) /4
- **Presentation and Response to Questions** (Assessment by the Jury) /4
- Supervisor's Assessment /3
- **Presentation of the Internship Report** (Assessment by the Jury) /3

III - Detailed syllabus by subject for Semester S1

Semestre: 1
Teaching Unit :UEF 1.1.1
Subject 1: Water Chemistry
VHS: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient : 2

Teaching Objectives:
To provide the fundamental chemistry principles necessary for the analysis and resolution of environmental problems; physicochemical characterization of water for the purpose of assessing its quality and treatment.

Recommended Prerequisite Knowledge:
Background in inorganic and analytical chemistry, as well as chemistry of solutions

Content of the Subject:
Part One – Chemistry of Natural Waters **10 Weeks**

1. Introduction
2. Suspended Solids
- Double-layer theory
- Stability of colloidal suspensions
- Turbidity and its measurement units
- Determination methods for suspended solids

3. Dissolved Substances
- Major and characteristic elements
- Units commonly used in water analysis
- Verification of water analysis results
- Salinity and mineral content
- Water hardness and titrations values
- Alkalinity and overall water composition
- Carbonate equilibria and calcite balance
- Assessment of water aggressiveness: Langelier index and graphs, Ryznar index, pH calculation, Puckorius scaling index, Stiff & Davis index, Larson index, Leroy index, and general aggressiveness indices

Part Two – Chemistry of Wastewater **(05 weeks)**

1. Introduction and Definitions

2. Characterization of Wastewater and Effluents

- Oxidizable matter content:
  - Biochemical Oxygen Demand (BOD_5)
  - Chemical Oxygen Demand (COD)
  - Total Organic Carbon (TOC)
- Kjeldahl Nitrogen (TKN)
- Content of particulate matter:
  - Suspended Solids (SS)
  - Volatile Suspended Solids (VSS)
- COD/BOD_5 ratio

Assessment Method : Continuous assessment: 40% and Final exam : 60%

Recommended Reading :

1. Monique Tardat-Henry and Jean-Paul Beaudry, *Water Chemistry*, Le Griffon d'Argile Editions, 1992.
2. Patrick Brezonik and William Arnold, *Water Chemistry: An Introduction to the Chemistry of Natural and Engineered Aquatic Systems*, Oxford University Press, USA, 2011.

Semester: 1
Teaching Unit: UEF 1.1.1
Subject 2: Air Pollution
Total Hours: 45h (Lecture: 3h00, Tutorial: 1h30)
Credits: 4
Coefficient :2

Teaching Objectives:

To acquire core insights into the workings of the atmosphere and build the necessary groundwork for analyzing critical air pollution issues.

Recommended Prerequisite Knowledge:

Basic concepts in general chemistry, chemical kinetics, and thermodynamics.

Subject Content :

1. Introduction
1. Introduction
- Chemical composition of the atmosphere, changes in constituent concentrations, chemical species residence times, and vertical atmospheric structure (layers, temperature, and pressure gradients).

2. Air Pollution Basics
- Types of air pollutants (regulated and unregulated)
- Units for pollutant concentrations and conversions between mass- and volume-based units
- Emission standards (Algerian and WHO)

3. Sources and Impacts of Air Pollution
- Human-made sources (transport, industry, energy) and natural sources (volcanic activity, lightning, pollen, etc.)
- Impacts on health, vegetation, and materials

4. Atmospheric Aerosols
- Composition and characteristics
- Formation processes; distinction between primary and secondary aerosols
- Relevant standards and regulations
- Aqueous-phase atmospheric chemistry and its link to acid rain
- Sampling and analysis methods for aerosols

5. Ozone Pollution and Precursors
- Tropospheric ozone and precursor compounds
- Formation mechanisms and environmental effects
- Sampling and analytical techniques for ozone (O_3)

6. Atmospheric and Tropospheric Chemistry
- Kinetics and photochemistry fundamentals, radical mechanisms, lifetimes, and photolysis
- Tropospheric chemistry
- Stratospheric ozone: sources, catalytic cycles (NOx, ClOx), and high-latitude O_3 depletion (ozone hole)

7. Meteorology and Pollutant Dispersion
- Influence of meteorological factors on the transport and spread of pollutants

Assessment Method: Continuous assessment: 40% Final exam: 60%

Recommended Reading :

1. J. C. Jones, *Atmospheric Pollution*, Book Boon, Ventus Publishing, 2008.

2. Louise Schriver-Mazzuoli, *Indoor Air Pollution*, Dunod Edition, 2009.
3. Zhongchao Tan, *Air Pollution and Greenhouse Gases*, Springer-Verlag, 2014.

Semester: 1
Teaching Unit: UEF 1.1.2
Subject 1: Fluid–Fluid Unit Operations (Extraction, Distillation, Absorption, and Stripping)
Total Hours: 67h30 (Lecture: 3h00, Tutorial: 1h30)
Credits: 6
Coefficient :3

Teaching Objectives:

By the end of this course, students should be able to:

- Master the separation techniques used in Process Engineering (absorption, extraction, and distillation).
- Understand the fundamentals of equipment sizing and design.
- Recognize the main operational issues (e.g., flooding, entrainment, etc.).

Recommended Prerequisite Knowledge:

Thermodynamics, differential equations, and transport phenomena (mass transfer, fluid mechanics, etc.).

Subject Content :

Chapter 1 – Absorption and Stripping (5 Weeks)

- **Introduction to Absorption and Stripping:**
  General concepts of absorption and desorption; classification of the main types of absorbers.
- **Physical Absorption:** Analysis of an absorption column, including:
  - Liquid–gas equilibrium
  - Gas solubility as a function of pressure and temperature
  - Material balances
  - Minimum liquid flow and operating flow rate
  - Concepts of theoretical and actual stages
  - McCabe–Thiele method
  - Phase transfer theories
  - Concept of transfer units
- **Absorption with Chemical Reaction:**
  Mass transfer in the presence of an irreversible first-order chemical reaction.
- **Stripping (Desorption):**
  Analysis of a desorption column, including:
  - Material balances
  - Minimum liquid flow and operating flow rate
  - Concepts of theoretical and actual stages
  - McCabe–Thiele method

Chapter 2 – Liquid–Liquid Extraction (4 Weeks)

- **Partition Coefficient and Selectivity:**
  Concept of partition coefficient, selectivity, and various types of equilibrium diagrams.
- **Equipment: Continuous and batch extraction units.**
- **Partially Miscible Solvents:**
  Multi-stage co-current and counter-current extraction (ternary diagram).
- **Immiscible Solvents:**
  Multi-stage co-current and counter-current extraction (McCabe–Thiele construction), extraction with dual feed, and extraction with reflux.
- **Solvent Recovery and Reuse:**
  Solvent stripping and recycling, selection of the extraction phase, and the concept of extraction efficiency.

Chapter 3 – Distillation (6 Weeks)

- **Continuous Distillation:**
  Ponchon–Savarit method, distillation of complex mixtures.
- **Batch Distillation**
- **Design of a Distillation Column**

Assessment Method: Continuous assessment: 40% and Final exam: 60%

Recommended References :

1. Daniel Defives and Alexandre Rojey, *Mass Transfer: Efficiency of Separation Operations in Chemical Engineering*, TECHNIP Edition, 1976.
2. Robert E. Treybal, *Mass Transfer Operations*, 3rd Edition, McGraw-Hill, 1980.
3. Warren L. McCabe, Julian C. Smith, Peter Harriott, *Unit Operations of Chemical Engineering*, 5th Edition, McGraw-Hill, 1993.
4. Jean Leybros, *Liquid–Liquid Extraction: Equipment Description*, Techniques de l'Ingénieur, Reference J2764 v1, 2004.
5. John J. McKetta (Ed.), *Unit Operations Handbook, Volume 1: Mass Transfer*, 1993.
6. Daniel Morvan, *Chemical Engineering: Unit Operations in Industrial Processes – Course and Solved Exercises*, ELLIPSES, Technosup Collection, 2009.
7. Pierre Wuithier, *Petroleum: Refining and Chemical Engineering*, 2nd Edition, 1972.
8. Marylee Z. Southard and Don W. Green, *Perry's Chemical Engineers' Handbook*, 9th Edition, 2019.
9. J. F. Richardson and J. H. Harker, *Chemical Engineering: Particle Technology and Separation Processes*, 5th Edition, Volume 2, 2002.
10. Fouad M. Khoury, *Multistage Separation Processes*, 3rd Edition, 2005.

Semester: 1
Teaching Unit: UEF 1.1.2
Subject 2: Heat Exchangers
Total Hours: 45h (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient : 2

Teaching Objectives:

This course is designed to expand students' understanding of heat transfer by covering advanced topics such as transient heat transfer, conduction through fins and around heat sources, and the principles of heat exchangers. It also provides instruction on methods for calculating and designing heat transfer equipment.

Recommended Prerequisite Knowledge:

Heat transfer, fluid mechanics, and basic mathematics, including first- and second-order differential equations and integral calculus.

Subject Content

Chapter 1 – Review of Heat Transfer Laws (1 Week)

- Refresher on fundamental heat transfer principles.

Chapter 2 – Flow Around Obstacles (4 Weeks)

- Flow over flat plates and around tubes, cylinders, and spheres; heat transfer coefficient correlations.
- Flow around tube bundles and corresponding correlations.

Chapter 3 – Flow Inside Tubes (3 Weeks)

- Internal flow analysis and estimation of heat transfer coefficients.

Chapter 4 – Heat Exchangers Without Phase Change (1 Week)

- Double-pipe exchangers, shell-and-tube exchangers (shell, tube bundle, and shell-and-tube assembly), and plate exchangers.

Chapter 5 – Heat Exchanger Design (3 Weeks)

- Heat transfer analysis: fundamental equations, logarithmic mean temperature difference, overall heat transfer coefficient (U)
- Pressure drop analysis: inside and outside the tubes
- Design methods: double-pipe exchangers and shell-and-tube exchangers (Kern method)
- General design considerations and calculation programming.

Chapter 6 – Heat Exchangers With Phase Change (3 Weeks)

- Equipment description
- Condensation of pure vapors: film coefficients, condenser calculations, subcooling and condensate cooling
- Condensation of mixed vapors: appropriate heat transfer coefficient (Ward and Kern methods), shell-side pressure drop, example calculations
- Reboilers: forced and natural circulation, pure substances and mixtures, submerged reboilers, example calculations

Assessment Method: Continuous assessment: 40% and Final exam: 60%

Recommended References :

1. J. F. Sacadura, *Heat Transfer – Introduction and Advanced Topics*, Lavoisier Edition, 2015.
2. R. B. Bird, W. E. Stewart, E. N. Lightfoot, *Transport Phenomena*, 2nd Edition, Wiley & Sons, 2007.
3. A. Giovannini and B. Bédat, *Heat Transfer*, Cépaduès Edition, 2012.
4. James R. Welty, Charles E. Wicks, Robert E. Wilson, Gregory Rorrer, *Fundamentals of Momentum, Heat, and Mass Transfer*, 4th Edition, Wiley & Sons, 2001.
5. Leontiev, *Theory of Heat and Mass Transfer*, Mir Edition, Moscow.
6. H. W. MacAdams, *Heat Transmission*, Dunod, Paris.
7. F. P. Incropera, D. P. DeWitt, *Fundamentals of Heat and Mass Transfer*, Wiley, New York, 2002.
8. Bontemps, A. Garrigue, C. Goubier, J. Huetz, C. Marvillet, P. Mercier, R. Vidil, *Heat Exchangers*, Techniques de l'Ingénieur, Traité Génie Énergétique.
9. P. Wuithier, *Petroleum: Refining and Chemical Engineering*, Volume 2, Technip Edition, Paris.

Teaching Unit: UEM 1.1
Subject 1: Water Chemistry Laboratory (Practical Work)
Total Hours: 22h30 (Practical: 1h30)
Credits: 2
Coefficient : 1

Teaching Objectives:
This course aims to provide students with the fundamental chemistry knowledge necessary for analyzing and solving environmental problems. It focuses on the physicochemical characterization of water to assess its quality and suitability for treatment**.**
Recommended Prerequisite Knowledge:
Solution chemistry, inorganic chemistry, and analytical chemistry.
Subject Content (Laboratory Sessions):

- Lab 1: Determination of salinity, pH, conductivity, and turbidity
- Lab 2: Determination of suspended solids and volatile suspended solids (VSS) [NF EN 872, June 2005]
- Lab 3: Determination of alkalinity and total alkalinity [NF EN ISO 9963-1, February 1996]
- Lab 4: Determination of total hardness, calcium hardness, and magnesium hardness [NF T90-003, August 1984; NF T90-016, August 1984]
- Lab 5: Determination of orthophosphates [NF EN ISO 6878, April 2005]
- Lab 6: Determination of dissolved oxygen
- Lab 7: Determination of biochemical oxygen demand (BOD_5)
- Lab 8: Determination of chemical oxygen demand (COD)
- Lab 9: Determination of total organic carbon (TOC)
- Lab 10: Determination of ammoniacal nitrogen and Kjeldahl nitrogen (TKN)
- Lab 11: Methodology for isolating microorganisms from soil, air, and water; microbiological analysis of water

Assessment Method: Continuous assessment: 100%

Recommended References :

1. Jean Rodier, Bernard Legube, Nicole Merlet, *Water Analysis: Natural Waters, Wastewaters, Seawater*, Dunod Edition, September 2016 – 10th Edition.*ean Rodier*

Semester: 1
Teaching Unit: UEM 1.1
Subject 2: Unit Operations Laboratory (Fluid–Fluid)
Total Hours: 22h30 (Practical: 1h30)
Credits: 2
Coefficient : 1

Teaching Objectives:

- Enable students to apply theoretical knowledge in practical settings and observe key physical and chemical phenomena.
- Develop teamwork skills, ensure adherence to safety rules, and understand the risks associated with equipment, installations, and processes.

Recommended Prerequisite Knowledge:
Thermodynamics and transport phenomena, including mass transfer and fluid mechanics.
Subject Content

- Lab 1: Determination of mutual solubility of two partially miscible liquids: water and phenol.
- Lab 2: Extraction of volatile compounds by hydrodistillation.
- Lab 3: Separation of benzoic acid and 2-naphthol.
- Lab 4: Study of a batch liquid–liquid extraction process.
- Lab 5: Analysis of selected phase diagrams.
- Lab 6: Physical absorption of CO_2 from an air stream into water.
- Lab 7: Absorption with chemical reaction and solvent regeneration: CO_2 absorption in amino acids.
- Lab 8: Gas–liquid absorption and desorption experiments.
- Lab 9: Construction of a ternary diagram: water/oil/surfactant.
- Lab 10: Study of the operation of a total reflux distillation column.
- Lab 11: Continuous rectification.
- Lab 12: Batch distillation.
- Lab 13: Study of a continuous distillation process in a packed column or a tray column.
- Lab 14: Separation and purification by fractional distillation: case study of an esterification reaction.

Assessment Method: Continuous assessment: 100%

Semester: 1
Teaching Unit: UEM 1.1
Subject 3: Heat Exchangers Laboratory (Practical Work)
Total Hours: 22h30 (Practical: 1h30)
Credits: 2
Coefficient : 1

Teaching Objectives:
- Experimentally quantify different modes of heat transfer.
- Measure the thermal performance of various types of heat exchangers.
- Experimentally study equipment for the generation, transport, and use of steam.

Recommended Prerequisite Knowledge:

Transport phenomena and fluid mechanics.

Subject Content – Laboratory Sessions:

- Lab 1: Heat conduction in a basic unit.
- Lab 2: One-dimensional (linear) heat conduction.
- Lab 3: Radial heat conduction.
- Lab 4: Convection and radiation heat transfer.
- Lab 5: Heat transfer by natural and forced convection.
- Lab 6: Coaxial (double-pipe) heat exchanger.
- Lab 7: Plate heat exchanger: enthalpy balances, efficiency curves, evaluation of heat transfer coefficients.
- Lab 8: Shell-and-tube (tube bundle) heat exchanger.

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Assessment Method: Continuous assessment: 100%

Semester: 1
Teaching Unit: UEM 1.1
Subject 4: Process Engineering Simulators
Total Hours: 37h30 (Lecture: 1h30, Laboratory/Practical: 1h00)
Credits: 3
Coefficient : 2

Teaching Objectives:

Through this course, students will learn to design, size, and simulate selected industrial processes related to process engineering using a computational simulator. The course content may be adapted depending on the specific simulator software employed.

Recommended Prerequisite Knowledge:
Thermodynamics, reaction kinetics, transport phenomena, unit operations, and reactors.

Subject Content

Course Content:
Chapter I – Introduction ***(2 weeks)***
- Process engineering simulators: creating a simulation, selecting the list of components, choosing a thermodynamic model, specifying and installing material streams, and simulating pumps, compressors, and flash separators.

Chapter II – Simulation of Chemical and Bioreactors ***(3 weeks)***
- Single and multiple conversion reactions, equilibrium reactions, perfectly stirred reactors (CSTRs), plug flow reactors (PFRs), bioreactors, catalytic reactors, and reactor combinations.

Chapter III – Simulation of Gas–Liquid, Liquid–Liquid, and Liquid–Solid Contactors ***(3 weeks)***
- Simulation of absorption/stripping processes with and without chemical reactions in columns of various configurations (trays and packings), liquid–liquid extraction, and liquid–solid extraction.

Chapter IV – Simulation of Distillation Columns ***(3 weeks)***
- Distillation of binary and multicomponent mixtures in columns of various configurations (tray and packed columns) with total or partial reflux and total or partial condensers.

Chapter V – Simulation of Real Industrial Processes ***(4 weeks)***
- Applications to real industrial processes.

Assessment Method:
- Continuous assessment 40% and Final exam: 60%

Recommended References :

1. Mariano Martín Martín, *Introduction to Software for Chemical Engineers*, 2014.
2. Xavier Julia, *Process Simulators*, Techniques de l'Ingénieur, Reference J1022, Volume 2.
3. User guide of the simulator software used in the course.

Semester: S1
Teaching Unit: UET 1.1.1
Course Title: Advanced Python Programming
Contact Hours (VHS): 45 hours (Lecture: 1h30, Practical Session: 1h30)
Credits: 2
Coefficient: 2

Subject Objectives

Targeted Competencies:
- Use of digital tools for the acquisition, processing, production, and dissemination of information
- Proficiency in Python programming and project management
- Skills in automation and data visualization

Objectives:
- To deepen mastery of the Python programming language and introduce students to the fundamentals of data analysis and artificial intelligence
- To acquire solid foundational knowledge in computer science
- To learn programming using Python and Excel
- To master task automation techniques
- To master the use of project management software

Required Materials:
- A computer with Python installed
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, os.listdir, os.path.exists, os.mkdir, os.rmdir, Seaborn, Plotly, Requests, Beautiful Soup, Tkinter, PyQt, etc.
- TensorFlow, PyTorch

Prerequisite:
- Python Programming

Subject Content

Chapter 1: Review of Python Programming ***(02 Weeks)***

1. **Introduction:** Basic concepts in computer science and digital tools; Python installation.
2. **Operating Systems:** Roles and types (Linux, Windows, etc.); priority management.
3. **Computer Networks:** Principles, IP addresses, DNS, Internet, etc.
4. **Basic Programming:** Interactive mode vs. script mode; variables; data types; operators; control structures (if, for, while).
5. **Functions and Core Elements:** Built-in functions and user-defined functions; standard modules (math, random); strings; lists; basic data manipulation.
6. **Files, Lists, Tuples, Dictionaries.**
7. **Exercises:**
   - Python practice exercises
   - Exercises using studied libraries (Math, Random, NumPy, Pandas, etc.)

Chapter 2: Programming and Automation *(04 Weeks)*

1. **Principles of Task Automation**
   - Python libraries for automation:
     - Pandas and NumPy
     - os, shutil (file and folder manipulation)
     - Openpyxl or Pandas (Excel/CSV file handling)
   - Definitions and examples of automation (e.g., sending emails)
2. **File Handling with Python:**
   - Browse directories (os.listdir)
   - Check file/folder existence (os.path.exists)
   - Create/delete folders (os.mkdir, os.rmdir)
   - Data visualization: Matplotlib, Seaborn, Plotly
   - Requests library for API interaction
   - Beautiful Soup for data scraping
   - Tkinter, PyQt for graphical interfaces
   - Copy/move files using shutil
   - Search, sorting, and simple report generation
   - Serialization and deserialization (pickle module)
   - Object serialization and large file processing (streaming)
3. **Exercises:**
   - Using openpyxl and pandas to read, modify, and write Excel/CSV files
   - Writing scripts to process text files (search, sorting)

- Automating technical calculations
- Generating simple reports (PDF, Excel)
- Sorting algorithms (including insertion sort)
- Implementing search functions
- File operations
- Secure navigation (basic network configuration, password management)

Chapter 3: Advanced Excel Training *(02 Weeks)*

1. Macros and creation of simple macros
2. Pivot tables
3. Histograms
4. Bar charts
5. Radar (Spider) charts
6. Excel practice exercises

Chapter 4: Introduction to GanttProject *(02 Weeks)*

1. Introduction to Project Management:
   - What is a project?
   - Project management challenges
   - GanttProject interface
2. Task management (creation, modification, organization)
3. Time management (start/end dates)
4. Resource management
5. Practical exercises using GanttProject

Chapter 5: Advanced Object-Oriented Programming *(03 Weeks)*

1. Code Organization:
   - Custom functions, parameters, return values
   - Modules, imports, packages
2. Complex Data Structures:
   - Lists, tuples, dictionaries (creation, modification, iteration)
3. Fundamental OOP Concepts:
   - Classes, objects, attributes, methods
   - Public, private, protected attributes
4. Special Methods:
   - __init__, __str__, __repr__, __len__
5. Advanced Concepts:
   - Encapsulation, abstraction, inheritance, polymorphism
   - Advanced inheritance, decorators, design patterns, metaclasses
6. Exercises

Chapter 6: Introduction to Data for Artificial Intelligence *(02 Weeks)*

1. Common AI datasets:
   - Iris
   - MNIST
   - CIFAR-10
   - Boston Housing
   - ImageNet
2. Data Preprocessing for Machine Learning:
   - Cleaning, normalization, encoding, data splitting
   - Cross-validation
3. Feature Engineering Techniques:
   - Feature selection
   - Feature creation
   - Dimensionality reduction
4. Essential AI Development Libraries:
   - Scikit-learn

   - TensorFlow
   - Keras
   - PyTorch
5. Exercises

Practical Work (Laboratory Sessions)
Lab 01: Mastering Python Fundamentals
(Control structures, data types, loops, simple functions)

- Introduction
- Reading and processing text files
- Generating simple reports (PDF, Excel)

Lab 02:
Developing specifications for a mini automation project in Python to automatically generate and email reports:

- Load data from a file (e.g., experimental measurements)
- Perform basic statistics (mean, standard deviation with interpretation)
- Generate a graph
- Send results via Python

Lab 03:

- Excel dashboard programming
- Automated Excel tables
- Simple macros
- Conditional formulas
- VLOOKUP

Lab 04: Organizing a Meeting Using GanttProject

- Create a new project
- Define tasks and subtasks
- Define resources (participants, equipment)
- Estimate durations
- Create and analyze the Gantt chart
- Monitor progress in real time

Lab 05: Advanced Structures and Code Organization
(Custom functions, dictionaries, modules, modular programming)
Lab 06: Advanced Object-Oriented Programming in Python
(Encapsulation, inheritance, special methods, simple design patterns)
Lab 07: File Handling and Data Analysis
(File I/O, text processing, introduction to Pandas and NumPy)
Lab 08: Data Preparation for Artificial Intelligence
(Loading AI datasets, cleaning, transformation, feature selection)

Final Project
Title: Data Analysis and Visualization with a Simple Predictive Model
Targeted Competencies:

- Data loading and processing
- Object-Oriented Programming (OOP)
- Advanced data structures
- Use of Pandas
- Use of Scikit-learn
- Oral presentation and written report preparation

Assessment Method :Final Examination: 60% and Continuous Assessment (CA): 40%

Bibliography

1. Schultz, E., & Bussonnier, M. (2020). *Python pour les SHS. Introduction à la programmation de données.* Presses Universitaires de Rennes.
2. Paroissin, C. (2021). *Pratique de la data science avec R: arranger, visualiser, analyser et présenter des données.* Paris: Ellipses.
3. Balech, S., & Benavent, C. (2019). *NLP Text Mining V4.0 – An Introduction (Doctoral Program Course).* Paris Dauphine.
4. Downey, A. B. (2015). *Think Python: How to Think Like a Computer Scientist.* O'Reilly Media.
5. Ramalho, L. (2022). *Fluent Python.* O'Reilly Media.
6. Swinnen, G. (2012). *Apprendre à programmer avec Python 3.* Eyrolles.
7. Matthes, E. (2019). *Python Crash Course: A Hands-On, Project-Based Introduction to Programming.* No Starch Press.
8. Cyrille, H. (2018). *Apprendre à programmer avec Python 3* (6th ed.). Eyrolles.
9. Daniel, I. (2024). *Apprendre à coder en Python.* J'ai lu.
10. Nicolas, B. (2024). *Python, du grand débutant à la programmation objet: Cours et exercices corrigés* (3rd ed.). Ellipses.
11. Ludivine, C. (2024). *Selenium: Maîtrisez vos tests fonctionnels avec Python.* ENI.

Online Resources

- Official Python Documentation: https://docs.python.org
- Python Exercises on Codecademy: https://www.codecademy.com/learn/learn-python-3
- W3Schools Python Tutorial: https://www.w3schools.com/python/

Semester: 1
Teaching Unit: UED 1.1
Elective Subject 1: Environmental Microbiology and Biochemistry
Contact Hours (VHS): 22 hours 30 minutes (Lecture: 1h30)
Credits: 1
Coefficient: 1

Teaching Objectives
To acquire fundamental knowledge in environmental microbiology.

Recommended Prior Knowledge
Basic knowledge in natural sciences.

Subject Content
Part I: Environmental Microbiology
I. Introduction to Environmental Microbiology
II. Morphology and Functional Anatomy of Bacteria
III. Bacterial Physiology
a) Nutrition
b) Growth
IV. Role of Microorganisms in Biogeochemical Cycles
a) Characteristics of microbial ecosystems
b) Interspecific interactions
c) Soil microbiology
d) Microbiology of aquatic environments
e) Air microbiology
V. Microbiology of Domestic and Wastewater
VI. Study of Microbial Biodiversity
1. Sampling
2. Microscopy
3. Flow cytometry
4. Selection and isolation techniques
5. Molecular methods
6. Other methods

Part II: Biochemistry
I. Introduction
a) Molecular constituents of the cell
b) Fundamentals of bioenergetics
II. Proteins
a) Structure and properties of amino acids
b) Structure and properties of proteins
III. Enzymology
a) Structure and mechanism of enzyme action
b) Fundamentals of enzyme kinetics
c) Introduction to enzyme classification
IV. Microbial Degradation of Proteins Nitrogen and sulfur cycles
V. Carbohydrates
a) Structure and properties of monosaccharides
b) Structure and properties of carbohydrates
c) Microbial degradation of cellulosic waste and the carbon cycle
d) Electron transport and the phosphorus and oxygen cycles
VI. Lipids
a) Structure and properties of fatty acids
b) Structure and properties of lipids
c) Microbial degradation of petroleum residues (e.g., n-alkanes)

Assessment Method

- Final Examination: 100%

Recommended References (if applicable)

1. Seagren, E. A., & Aydilek, A. H. (2010). Biomediated Geomechanical Processes. In *Environmental Microbiology*, edited by Ralph Mitchell & Ji-Dong Gu. Wiley & Sons, pp. 319–348.
2. Doran, P. M. (2013). *Bioprocess Engineering Principles* (2nd ed.). Academic Press.
3. Clarke, K. G. (2013). *Bioprocess Engineering*. Elsevier.
4. Pellet, P. E. (1968). *La Cellule: Structure et Fonctions*. Masson & Cie, Paris.
5. Quentin, F., Gallet, P.-F., Guilloton, M., & Quintard, B. (2011–2015). *Biochimie en 84 fiches* (2nd ed.). Dunod, Paris.

III – Detailed Program by Subject for Semester S2

Semester: 2
Teaching Unit: UEF 1.2.1
Subject 1: Drinking Water Production
Contact Hours (VHS): 67h30 (Lecture: 3h00, Tutorial: 1h30)
Credits: 6
Coefficient: 3

Teaching Objectives
The aim of this course is to provide students with the tools necessary for the management of drinking water production processes.

Recommended Prior Knowledge
- Water chemistry
- Solution chemistry
- Electrochemistry
- Mass transfer

Subject Content
Chapter 1: General Principles and Standards *(2 weeks)*
- General qualities of water from various sources
- Quality standards
- Guidelines for water treatment
- Treatment process flows

Chapter 2: Drinking Water Production Processes *(5 weeks)*
- **Micro-straining**: Theoretical aspects; service life; selection criteria
- **Coagulation and Flocculation**: Suspended particles; coagulation process; flocculation theory
- **Sedimentation**: Types of sedimentation; sedimentation of discrete and flocculant particles; tube and lamella sedimentation
- **Flotation**: Flotation units; performance considerations
- **Filtration**: General principles; characteristics of filter media; water flow through a sand filter; dual-media filters
- **Disinfection**: General principles; methods including chlorine, chlorine dioxide, ozone, UV, UV/hydrogen peroxide, etc.

Chapter 3: Specific Drinking Water Treatment Processes *(8 weeks)*
- **Softening by precipitation**
- **Adsorption and ion exchange**
- **Iron and Manganese Removal**: Equilibrium considerations; deferrization and demanganization processes
- **Water Stabilization**
- **Fluoridation and Defluoridation**
- **Desalination of seawater and brackish water**: Methods include distillation, freezing, electrodialysis, reverse osmosis, etc.
- **Advanced Oxidation Processes (AOPs)**: Fenton, Electro-Fenton, Photo-Fenton, UV/Ozone, UV/Ozone/H_2O_2, sonochemistry, photocatalysis, plasma processes, electron beam, etc.
- **Swimming Pool Water Treatment**: Objectives and techniques

Assessment Method
- Continuous Assessment (CA): 40% and Final Examination: 60%

Recommended References
- Legube, B. *Production d'eau potable*. Dunod, Paris
- Beaudry, J. B. *Traitement des eaux*. Le Griffon d'Argile, Sainte-Foy, Canada
- Degremont. *Mémento technique de l'eau*, Volumes 1 & 2. Edition Technique et Documentation, Paris

- Masschelein, W. J. *Unit Processes of Water Treatment*
- Hasley, C., & Leclerc, H. *Microbiology of Drinking Water*
- Cardot, C. *Water Treatment for Engineers – Physico-Chemical and Biological Processes: Course and Solved Problems*
- Desjardins, R. *Water Treatment*
- Crini, G., & Badot, P. M. *Treatment and Purification of Industrial Wastewater: Membrane Processes, Bioadsorption, and Chemical Oxidation*

Semester: 2
Teaching Unit: UEF 1.2.1
Subject 2: Solid Waste Management and Treatment
Contact Hours (VHS): 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Teaching Objectives

The aim of this course is to introduce students to the challenges of solid waste, whose impact on the environment and public health is well-documented. The course focuses on studying different treatment options depending on the type of waste.

Subject Content

Introduction

- Definition of waste
- Classification of wastes
- Characterization
- Ultimate waste
- Legislation

Chapter 1: Household Waste

- **Collection:** Types of collection, collection equipment, collection routes, transfer stations
- **Landfilling:** Issues of illegal dumping, sanitary landfills (SLFs), admissible wastes for Class I, II, and III SLFs, technical characteristics of SLFs (passive safety, active safety, cover), leachate treatment and biogas valorization, landfill design
- **Bioconversion of Organic Waste**
- **Composting:** Advantages, compostable wastes, composting parameters, composting phases, composting methods, assessment of compost maturity, vermicomposting
- **Methanization (Anaerobic Digestion):** Suitable wastes, importance of methane in industrial processes, phases of methanization, parameters, dry and wet fermentation, biogas treatment, types of digesters
- **Incineration:** Purpose, products from household waste incineration, incineration parameters, post-treatment of gases, fly ash, and bottom ash, types of furnaces
- **Recycling:** Importance of recycling, recycling symbols, recyclable vs. non-recyclable wastes, significance of selective sorting

Chapter 2: Special Industrial Waste (SIW)

- Definition, types, sources, hazard criteria, nomenclature, storage
- **Treatment Methods:**
  - **Physico-chemical:** Neutralization, chemical precipitation, oxidation/reduction, sorption, stabilization/solidification, injection into wells
  - **Thermal:** Incineration, pyrolysis, hydrothermal oxidation, vitrification

Chapter 3: Healthcare Waste / Infectious Risk Waste (HW/IRW)

- Types of medical waste, legislation, sorting, packaging and labeling, storage, transport
- **Treatment Methods:** Incineration, autoclave sterilization, chemical disinfection, microwave irradiation

Assessment Method

- Continuous Assessment (CA): 40% and Final Examination: 60%

References

1. Tchobanoglous, G., & Kreith, F. (2002). *Handbook of Solid Waste Management*. McGraw-Hill.
2. Vallero, D. A., & Peirce, J. J. (2003). *Engineering the Risks of Hazardous Wastes*. B.H. Ed.
3. Wang, L. K., Shammas, N. K., & Hung, Y.-T. (2009). *Advances in Hazardous Industrial Waste Treatment*. CRC Press.

Semester: 2
Teaching Unit: UEF 1.2.2
Subject 1: Adsorption Processes and Membrane Separation
Contact Hours (VHS): 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Teaching Objectives

The course aims to provide:

- The theoretical foundations necessary to implement an adsorbent and design various types of adsorbers: batch, semi-continuous, and continuous.
- In-depth theoretical and practical knowledge in membrane techniques and familiarize students with the latest technological advances in membrane processes.

Recommended Prior Knowledge

- Transfer phenomena (mass transfer, fluid mechanics, etc.)
- Surface chemistry and heterogeneous catalysis

Subject Content

Part I: Adsorption Processes *(7 Weeks)*

Chapter 1: Industrial Adsorbents

- Main industrial adsorbents
- Selection criteria
- Regeneration methods
- Major industrial applications

Chapter 2: Adsorption Dynamics

- Review of general physical adsorption laws

Chapter 3: Batch and Continuous Processes

- Breakthrough curves

Chapter 4: Adsorption Separation Processes

- Pressure-swing adsorption (PSA)
- Temperature-swing adsorption (TSA)

Chapter 5: Adsorption Kinetics

- Calculation of adsorption rates
- Pseudo-first and second-order kinetic models
- Intra- and extra-particle diffusion models

Part II: Membrane Separation Processes *(8 Weeks)*

Chapter 1: General Principles and Definitions

Chapter 2: Membranes

- Structure, characterization, and membrane modules in industrial installations

Chapter 3: Membrane Separation Techniques

- Microfiltration
- Ultrafiltration
- Nanofiltration
- Reverse osmosis
- Electrodialysis

Assessment Method: Continuous Assessment (CA): 40% and Final Examination: 60%

Recommended References

1. McKetta, J. J. (Ed.). (1993). *Unit Operations Handbook, Volume 1: Mass Transfer*.
2. McCabe, W. L., Smith, J. C., & Harriott, P. (1993). *Unit Operations of Chemical Engineering* (5th ed.). McGraw-Hill.
3. Brun, J. P. (1988). *Membrane Separation Processes: Transport, Membrane Techniques, Applications*. Masson, Paris.
4. Treybal, R. E. (1980). *Mass Transfer Operations* (3rd ed.). McGraw-Hill.

Semester: 2
Teaching Unit: UEF 1.2.2
Subject 2: Physico-Chemical Treatment of Wastewater
Contact Hours (VHS): 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Teaching Objectives

Understand the role of physico-chemical wastewater treatment within the treatment chain, both as a preliminary treatment and as a complementary treatment, in order to design and manage wastewater treatment plants.

Recommended Prior Knowledge

Fundamental concepts in chemistry and chemical/process engineering.

Subject Content

1. Introduction to Wastewater Treatment

2. Characterization and Quantification of Wastewater

- Quality Characterization: BOD, COD, TSS, nitrogen, phosphorus, oils and grease, hydrocarbons, toxic elements, heavy metals, temperature, pH, etc.
- Quantification: Flow rates (average, peak coefficient, maximum dry weather flow, maximum wet weather flow), techniques for flow measurement
- Evaluation of source-reduction techniques for wastewater
- Flow regulation and attenuation (design of equalization basins)

3. Wastewater Collection and Pumping

- Design of sewer systems to convey different wastewater sources (based on population, flow, load) – types of sewer networks
- Design of pumping stations to transmit wastewater to treatment plants and discharge treated effluents to receiving environments

4. Proposed Wastewater Treatment Chains

- Selection and design of treatment stages according to wastewater composition and effluent destination
- Protection of receiving environments (rivers, dams, groundwater, seas), public health protection, reuse of treated wastewater (agriculture, industry, etc.), aquifer recharge

5. Physico-Chemical Treatments

- Influent channels: Design and flow regulation techniques
- Screening (grillage): Objectives, types of screens, calculation of head loss and wetted area for clean and clogged screens, approach velocity and passage velocity, quantity of retained debris
- Grit Removal: Channel grit chambers, aerated or tangential; objectives, operation, dimensioning, air requirements, quantity of retained grit
- Oil and Grease Removal (Skimming/Greasing): Static and aerated skimming, objectives, operation, dimensioning
- Chemical Treatment: Buffer and phosphorus removal basins, objectives, operation, dimensioning, dose optimization
- Sedimentation and Clarification: Objectives; discrete sedimentation, flocculant sedimentation, lamella sedimentation, zone sedimentation, compressive sedimentation; dimensioning of primary and secondary clarifiers (shape, inlet, outlet weir, bottom, sludge extraction system, etc.)
- Aeration and Agitation: Techniques, implementation, and control parameters
- Troubleshooting and Remediation: Diagnostic techniques and implementation of remediation procedures for physico-chemical treatments

Assessment Method : Continuous Assessment (CA): 40% and Final Examination: 60%

Semester: 2
Teaching Unit: UEM 1.2

Subject 1: Porous and Dispersed Media
Contact Hours (VHS): 37h30 (Lecture: 1h30, Tutorial: 1h00)
Credits: 3
Coefficient: 2

Teaching Objectives
This course aims to provide a solid understanding of process engineering operations for the treatment of liquids and gases.
Recommended Prior Knowledge Unit operations
Subject Content
Chapter 1: Introduction to Porous and Dispersed Media
- Natural porous media
- Artificial porous media
- Solid operations: Grinding, Screening, Sieving
- Dispersed media

Chapter 2: Characterization of Porous Media
- Grain morphology
- Morphology of a grain population
- Particle size distribution
- Classification of solid particles
- Characterization of a granular bed

Chapter 3: Particle Motion in Fluids
- Vertical motion of particles
- Calculation of particle settling velocity (terminal velocity)
- Sedimentation of particle suspensions
- Motion of colloids
- Motion of drops and bubbles

Chapter 4: Fluid Flow Through Porous Media
- Review: Bernoulli's continuity equation
- Darcy's law
- Relationship between Bernoulli's continuity equation and Darcy's law
- Permeability of a porous medium
- Kozeny-Carman model
- Consistency between Darcy's law and Kozeny-Carman equation
- Burke-Plummer model

Chapter 5: Filtration
- Filtration theory
- Filtration theory with support media
- Constant flow filtration
- Constant pressure filtration

Assessment Method
- Continuous Assessment (CA): 40% and Final Examination: 60%

Recommended References

1. **Coulson, J. M., Richardson, J. F., Backhurst, J. R., & Harker, J. H. (2002).** ***Chemical*** *Engineering*, Volume 2, 5th Edition, Pergamon Press.
2. Rhodes, M. (2008). *Introduction to Particle Technology*, 2nd Edition, Wiley.
3. Gibilaro, L. G. (2001). *Fluidization Dynamics*, Butterworth-Heinemann.
4. Perry, R. H., Green, D. W., & Maloney, J. O. (1999). *Perry's Chemical Engineers' Handbook*, 7th Edition, McGraw-Hill.
5. Kunii, D., & Levenspiel, O. (1991). *Fluidization Engineering*, 2nd Edition, Butterworth-Heinemann.
6. Darton, R. C. (1985). *Fluidization*, ed. by Davidson, J. F., Clift, R., & Harrison, D., Academic Press.
7. McCabe, W. L., Smith, J. C., & Harriott, P. (2004). *Unit Operations of Chemical Engineering*, 7th Edition, McGraw-Hill.

Semester: 2
Teaching Unit: UEM 1.2
Subject 2: Laboratory: Water Treatment and Adsorption & Membrane Separation Processes
Contact Hours (VHS): 22h30 (Practical: 1h30)
Credits: 2
Coefficient: 1

Teaching Objectives
The objective of this laboratory is to present the water treatment processes and the adsorption and membrane separation techniques most commonly used by engineers to produce potable water.

Recommended Prior Knowledge
Water chemistry, physico-chemical analytical methods

Laboratory Content
Water Treatment
- Coagulation-flocculation
- Lime decarbonation
- Ion exchange
- Sedimentation
- Clarification
- Filtration
- Sterilization by chlorination (breakpoint) or ozonation
- Aeration (determination of mass transfer coefficient)
- Agitation (optimization of velocity gradients in treatment systems)
- Membrane processes

Adsorption and Membrane Separation Processes
- Separation of a dye from aqueous solution by adsorption
- Separation of a pesticide from aqueous solution by adsorption
- Heterogeneous system equilibrium: experimental determination of the adsorption isotherm of CH_3COOH dissolved in water by a solid substance (activated carbon)
- Extraction by emulsion liquid membrane
- Preparation and stabilization of an emulsion

Assessment Method:
- Continuous Assessment: 100%

Recommended References

1. J.B. Beaudry, *Traitement des eaux*, Edition le Griffon d'argile, Sainte-Foy, Canada
2. DEGREMONT, *Mémento technique de l'eau*, Edition Technique et Documentation, Paris
3. W.W. Eckenfelder, *Urban and Industrial Wastewater Management*, Edition Technique et Documentation, Paris
4. M.J. Hammer, *Water and Wastewater Technology*, John Wiley & Sons, New York
5. McCabe, W.L., Smith, J.C., & Harriott, P., *Unit Operations of Chemical Engineering*, 5th Edition, McGraw-Hill, 1993
6. J.P. Brun, *Membrane Separation Processes: Membrane Transport Techniques and Applications*, Masson, Paris, 1988

Semester: 2
Teaching Unit: UEM 1.2
Subject 3: Process Water Treatment and Conditioning
Contact Hours (VHS): 45h00 (Lecture: 1h30; Tutorial: 1h30)
Credits: 4
Coefficient:2

Teaching Objectives

The goal of this course is to provide theoretical and practical knowledge on the treatments required to use water as an energy and heat transfer fluid. This includes addressing problems such as fouling, scaling, corrosion, biological growth, and water quality issues that arise directly from the use of water in industrial processes.

Recommended Prior Knowledge

Water chemistry

Subject Content

Chapter I: Water for Different Processes – Quality and Characteristics

- I.1. Water for the food industry
- I.2. Water for the pharmaceutical industry
- I.3. Water for the chemical industry
- I.4. Water for the paper industry
- I.5. Problems caused by feed water
- I.6. Appropriate water treatments

Chapter II: Boiler Water Treatment

- II.1. Boiler water specifications (characteristics, properties)
- II.2. Problems with makeup water
- II.3. Boiler water treatment
  - II.3.1. Softening by ion exchange
  - II.3.2. Demineralization
  - II.3.3. Degassing
  - II.3.4. Corrosion inhibitors
  - II.3.5. Anti-priming conditioning
- II.4. Treatment processes

Chapter III: Cooling Water Treatment

- III.1. Cooling circuits (open circuits, fully closed circuits, semi-closed circuits)
- III.2. Water cooling
- III.3. Problems caused by water use in cooling circuits: scaling, fouling, corrosion, microbial growth
- III.4. Cooling water treatment
  - III.4.1. Makeup water treatment
    - III.4.1.1. Precipitation softening
    - III.4.1.2. Dispersing and recalcitrant agents
  - III.4.2. Blowdown treatment

Assessment Method: Continuous Assessment: 40% and Final Examination: 60%

Recommended References

1. *Boiler Water: Problems and Solutions*, PDH Course M165
2. *Industrial Cooling Systems*, December 2001, European Commission
3. Bhatia, A., *Cooling Water Problems and Solutions: Quick Book*, 2015
4. *Cooling Water Treatment: Essential Expertise for Water, Energy and Air*, Annual Report, 2010
5. *Boiler Water Treatment: Principles and Practice*, Volumes 1 and 2

Seme

Semester: 2
Teaching Unit: UET 1.2
Subject: Compliance with Standards, Ethics, and Integrity
Contact Hours (VHS): 22h30 (Lecture: 1h30)
Credits: 1
Coefficient: 1

Subject Objectives:

The course aims to raise students' awareness of ethical principles and rules that govern life at the university and in the professional world. It also seeks to:

- Encourage respect for intellectual property.
- Explain the risks of moral misconduct such as corruption and ways to combat it.
- Alert students to ethical challenges posed by new technologies and sustainable development.

Recommended prior knowledge:

Foundations in ethics and professional deontology.

Subject Content:

A. Respect for Ethics and Integrity

1. **University Ethics Charter (MESRS):**
   - Integrity and honesty
   - Academic freedom
   - Mutual respect
   - Commitment to scientific truth, objectivity, and critical thinking
   - Fairness and equity
   - Rights and responsibilities of students, faculty, and administrative and technical staff
2. **Responsible Research:**
   - Ethical principles in teaching and research
   - Responsibilities in teamwork: professional equality, anti-discrimination, pursuit of the public interest
   - Responsible conduct and combating misconduct: scientific fraud, plagiarism (definitions, forms, preventive measures, detection, sanctions), data falsification and fabrication
3. **Ethics and Professional Conduct in the Workplace:**
   - Legal confidentiality
   - Loyalty and responsibility within the company
   - Conflict of interest
   - Integrity: forms of corruption, consequences, methods to fight corruption, and sanctions

B. Intellectual Property

I. Fundamentals of Intellectual Property:

- Industrial property, literary and artistic property
- Rules for citing references (books, scientific articles, conference communications, theses, dissertations, etc.)

II. Copyright:

- Copyright in the digital environment (databases, software, open-source software)
- Copyright on the Internet and e-commerce (domain names, websites, social networks)

III. Patents:

- Definition, rights, usefulness, patentability, application procedures in Algeria and worldwide

IV. Protection and Valorization of Intellectual Property:

- How to protect intellectual property
- Violations and legal remedies
- Valorization of intellectual property
- Protection of intellectual property in Algeria

C. Ethics, Sustainable Development, and New Technologies:

- Links between ethics and sustainable development, energy efficiency, bioethics, and emerging technologies (AI, scientific advances, humanoids, robots, drones).

Assessment Method:

- Examination: 100%

Recommended References:

1. University Ethics and Deontology Charter: MESRS PDF
2. Arrêtés N°933 (2016) – Prevention and fight against plagiarism
3. Prairat, E. *De la déontologie enseignante*, Paris, PUF, 2009
4. Racine, L., Legault, G.A., Bégin, L. *Éthique et ingénierie*, Montréal, McGraw Hill, 1991
5. Siroux, D. *Déontologie: Dictionnaire d'éthique et de philosophie morale*, Paris, Quadrige, 2004
6. Medina, Y. *La déontologie, ce qui va changer dans l'entreprise*, 2003
7. Didier, Ch. *Penser l'éthique des ingénieurs*, Presses Universitaires de France, 2008
8. Gavarini, L., Ottavi, D. *Éditorial de l'éthique professionnelle en formation et en recherche*, 2006
9. Caré, C. *Morale, éthique, déontologie*, Administration et éducation, 2002
10. Jacquet-Francillon, F. *Notion: déontologie professionnelle*, 2000
11. Carr, D. *Professionalism and Ethics in Teaching*, Routledge, 2000
12. Galloux, J.C. *Droit de la propriété industrielle*, Dalloz, 2003
13. Wagret, F., J-M. *Brevet d'invention, marques et propriété industrielle*, PUF, 2001
14. Dekermadec, Y. *Innover grâce au brevet*, 1999
15. AEUTBM. *L'ingénieur au cœur de l'innovation*, Université de Technologie Belfort-Montbéliard
16. Appasso
17. Université Rennes 2 – Intellectual Property Course
18. Rinck, F., Mansour, L. *Literacy in the digital age: copy-paste among students*, Université Grenoble 3 & Université Paris Ouest Nanterre, France
19. UNESCO, *L'ABC du droit d'auteur*
20. Alain Bensoussan, *Livre blanc – Une science ouverte dans une république numérique*, CNRS
21. *Copyright in the Cultural Industries*, Cheltenham, E. Elgar, 2002
22. Groupe de travail sur le plagiat électronique, CREPUQ
23. Chiriac, E., Filiatrault, M., Régimbald, A., *Guide de l'étudiant : l'intégrité intellectuelle* (2014)
24. Université de Montréal, *Stratégies de prévention du plagiat* (2010)
25. Malissard, P., *La propriété intellectuelle: origine et évolution*, 2010
26. World Intellectual Property Organization: www.wipo.int.

Semestre: 2
Unité d'enseignement: 1.2.1
Matière: Applied Artificial Intelligence Fundamentals
Contact Hours (VHS): 45h00 (Lecture: 1h30, Lab/TP: 1h30)
Crédits: 2
Coefficient: 2

Targeted Skills:
- Identify opportunities for artificial intelligence (AI) in engineering sciences.
- Understand the ethical implications of AI and best practices for its use.
- Apply AI techniques to problem-solving.

Objectives:
- Master AI algorithms.
- Introduction to fundamental concepts, tools, and applications of modern AI, with a focus on practical exercises using Python.
- Deepen Python programming skills.
- Understand AI approaches for problem-solving.

Prerequisites:
- Advanced Python programming.

Required Materials:
- Computer with Python installed.
- Python libraries: NumPy, Pandas, Scikit-learn, Matplotlib, Seaborn, Plotly, Requests, Beautiful Soup, Tkinter, PyQT, TensorFlow, PyTorch, Keras, etc.

Subject Content:

Chapter 1: Introduction to AI (1 week)
- Definitions and fields of application.
- Historical evolution of AI.
- Introduction to main domains: Machine Learning (ML) and Deep Learning (DL).

Chapter 2: Basic Mathematics for AI (1 week)
- Linear algebra: vectors, matrices, products, norms.
- Probability & statistics: variables, expectation, variance, common distributions (normal, binomial, uniform).
- Simple linear regression: formulation, cost function, optimization, implementation with Scikit-learn.
- Exercises using NumPy and Matplotlib.

Chapter 3: Machine Learning (3 weeks)
- Key concepts: data, models, features, labels, generalization.
- Learning pipeline: training, validation, testing.
- Types of learning: supervised, unsupervised, reinforcement (overview).
- Practical exercises on datasets.

Chapter 4: Supervised Classification (3 weeks)
- Model training principles.
- Algorithms: Support Vector Machines (SVM), Decision Trees.
- Performance evaluation: confusion matrix, accuracy, recall, F1-score.
- Hands-on exercises using Scikit-learn.

Chapter 5: Unsupervised Learning
- Clustering: K-means, DBSCAN.
- 2D visualization and interpretation of results.
- Exercises on datasets.

Chapter 6: Neural Networks and Deep Learning
- Architecture: perceptron, layers, weights, biases, activation functions (ReLU, Sigmoid, Softmax).
- Introduction to Deep Learning and Convolutional Neural Networks (CNN).
- Exercises using TensorFlow and PyTorch (e.g., text analysis, image classification).

Chapter 7: Mini Project
- Build a complete classification or clustering model: preprocessing, training, visualization.
- Example projects: handwritten character recognition, natural disaster prediction, chatbot, anomaly detection in machine sounds, sentiment analysis of social media posts.

Lab Work (TP):
- **TP01:** Python environment setup and libraries.
- **TP02:** Simple regression and visualization with Matplotlib.
- **TP03:** Machine Learning pipeline and data splitting.
- **TP04:** Supervised classification with Scikit-learn.
- **TP05:** Unsupervised clustering (K-means, DBSCAN) and visualization.
- **TP06:** Simple neural network with TensorFlow, PyTorch, or Keras; simple CNN for image classification (e.g., MNIST dataset).

Evaluation:
- Continuous assessment: 40%
- Final exam: 60%

References:

1. Ganascia, J. G. (2024): *AI Explained to Humans*, Le Seuil, Paris.
2. Anglais, L., Dilhac, A., Dratwa, J., et al. (2023): *Ethics at the Heart of AI*, Quebec, Obvia.
3. Robert, J. (2024): *Natural Language Processing (NLP): Definition and Principles* – Link
4. Challet, F.: *Deep Learning with Python*, Eyrolles.
5. Bersini, H. (2024): *Practical AI with Python*, Eyrolles.
6. Prieur, B. (2024): *Natural Language Processing with Python*, Eyrolles.
7. Mathivet, V. (2024): *Python Implementation with Scikit-learn*, Eyrolles.
8. Dubertret, G. (2023): *Introduction to Cryptography with Python*, Eyrolles.
9. Chazallet, S. (2023): *Python 3 – Language Fundamentals*, Eyrolles.
10. Belhadef, H., Djemal, I.: *TALN Method*, University of M'sila, Algeria.

V- Detailed program by subject for Semester S3

Semester: 3
Teaching Unit: UEF 2.1.1
Subject 1: Theoretical Foundations and Biological Treatment of Wastewater
Contact Hours (VHS): 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Subject Objectives:
Understand the fundamentals of biological wastewater treatment, including the modeling and design of various types of biological reactors.
Recommended Prerequisites:
Basic knowledge of biochemistry, microbiology, and process engineering.
Course Content:

1. **Introduction:** Objectives and necessity of biological treatment.
2. **Composition and Classification of Microorganisms:**
    - Introduction to microbial metabolism and biological reactions (carbon sources, energy sources, nutritional requirements of microorganisms).
    - **Metabolism of decomposers:**
        - Conversion and growth conditions
        - Microbial growth and Monod kinetics (Monod model and bio-kinetic constants; specific growth rate, substrate utilization rate, oxygen consumption rate)
        - Determination of Monod bio-kinetic constants (batch technique, continuous reactor technique)
        - Different pathways for the biological degradation of pollutants in wastewater (aerobic, anoxic, and anaerobic pathways)
        - Modeling of biological treatment (competition model, inhibition model, ASM1, etc.)
3. **Biological Treatment Techniques:**
    - Suspended biomass processes
    - Attached biomass processes
4. **Examples of Biological Treatment Techniques:**
    - Activated sludge systems
    - Biological filters
    - Membrane reactors
    - Lagoon systems
5. **Activated Sludge Systems:**
    - Types of activated sludge (high load, medium load, extended aeration); sludge age and mass loading
    - Mass balance development for activated sludge systems with recycle (sludge age, mass loading, determination of substrate and biomass concentrations at the outlet, aeration tank volume, excess sludge quantity, oxygen and air requirements)
    - Design of an activated sludge system
    - Use of activated sludge for carbon and nitrogen removal
    - Use of activated sludge for carbon, nitrogen, and phosphorus removal
    - Different configurations of activated sludge reactors (biological tank, channel, sequential, plug-flow, etc.)
6. **Sludge Treatment:**
    - Quantification of sludge generated in a biological treatment system
    - Sludge dewatering and treatment (thickening, aerobic digesters, anaerobic digesters, drying beds, filter press)
7. **Malfunctions and Remediation Techniques in Biological Treatment:**
    - Sludge deflocculation, bulking, and foaming (diagnostic techniques and implementation of remediation procedures)

Evaluation Method: Continuous assessment: 40% ; Final exam: 60%.

Semester: 3
Teaching Unit: UEF 2.1.1
Course 2: Treatment of Gaseous Effluents

Contact Hours: 45h00 (Lecture: 1h30, Tutorial: 1h30)
Credits: 4
Coefficient: 2

Subject Objectives:
Introduce students to the different treatment processes for gases and dust produced by stationary and mobile units.
Recommended Prerequisites:
Basic knowledge related to treatment processes (absorption, adsorption, filtration, etc.)
Subject Content:
Chapter 1: General Overview of Air Pollution and Gaseous Effluents
- Sources of pollution
- Main air pollutants
- Main methods for treating these pollutants

Chapter 2: Treatment Processes for Gaseous Effluents from Stationary Sources
- Absorption: gas-liquid contactors, design of packed columns with and without chemical reaction, design of tray columns
- Adsorption
- Thermal oxidation, catalytic oxidation
- Condensation, biofiltration, flaring

Chapter 3: Treatment Processes for Dust from Stationary Sources
- Bag filters, cyclones, Venturi scrubbers, electrostatic precipitators

Chapter 4: Pollution Treatment from Mobile Sources
- Gasoline and diesel vehicles: emitted pollutants, emission standards, catalytic converters, two-way and three-way catalysts, etc.

Chapter 5: Measurement of Gases and Particles
- Sampling and analysis

Evaluation Method:
Continuous assessment: 40% ; Final exam: 60%
References:

1. Kenneth C. Schifftner, *Air Pollution Control Equipment Selection Guide*, Lewis Publishers, 2002
2. Nicholas P. Cheremisinoff, *Handbook of Air Pollution Prevention and Control*, B.H. Ed., 2002
3. Lawrence K. Wang, Yung-Tse Hung, Nazih K. Shammas, *Advanced Physicochemical Treatment Processes*, Handbook of Environmental Engineering, Vol. 4, HumanaPress, 2006
4. *Technique de l'ingénieur*: Ti452 Chemical Engineering and Environmental Protection, 5th edition
5. J. L. Coulson, J. F. Richardson, and R. K. Sinnott, *Chemical Engineering*, 3rd edition, vol. 6, Butterworth Heinemann, 1999
6. M. Roustan, *Gas-Liquid Transfers in Water and Gaseous Effluent Treatment Processes*, Tec & Doc, Paris, 2003
7. M. Roustan, “Absorption in Air Treatment,” *Techniques de l'Ingénieur*, vol. 33, 2004
8. P. Trambouze, H. Van Landeghem, and J.-P. Wauquier, *Chemical Reactors: Design, Calculation, Implementation*, Technip, Paris, 1984
9. C. Roizard and G. Wild, “Absorption with Chemical Reaction,” *Techniques de l'Ingénieur*, vol. 1, 1997, Online
10. P. V. Danckwerts, *Gas-Liquid Reactions*, 1970

Semester: 3
Teaching Unit: UEF 2.1.2
Subject 1: Technical Thermodynamics
Total Hours (VHS): 45h00 (Lecture: 1h30, Tutorial/Practical Work: 1h30)

Credits: 4
Coefficient: 2

Teaching Objectives:
Study thermodynamic cycles and master the operating principles of certain energy technologies, namely: heat engines, compressors, pumps, etc.
Recommended Prior Knowledge:
Chemical Thermodynamics, Fluid Mechanics.
Course Content:
Chapter 1 (8 weeks)
Carnot cycle of heat engines, thermal efficiency. Internal combustion engine. Gas turbine. Steam engine (Rankine cycle, HIRN cycle, reheat cycle, extraction cycle) with representation in various diagrams ((T,S), (P,V), and (H,S)).
Chapter 2 (4 weeks)
Compressors and pumps (compressor cycle, work, efficiency, and calculation of the number of stages). Pump installations (characteristic curves, head, available NPSH, required NPSH, efficiency).
Chapter 3 (3 weeks)
Refrigeration: Thermodynamic study (reversed Carnot cycle). Real refrigeration cycles. Heat pumps.
Assessment Method:
Continuous assessment: 40%; Final exam: 60%.
Recommended References:

1. Gordon Van Wylen, Richard Sonntag, *Applied Thermodynamics*, ERPI Publisher, Diffusion Pearson Education Collection, 2002.
2. Cycle Thermo Machines PDF
3. Machines Thermiques - EMSE PDF
4. Olivier Cleynen, *Engineering Thermodynamics*, Frama Book Collection, 2015.
5. Paul Chambadal, *Gas Turbines*, Collection of the French Electricity Studies and Research Directorate, Eyrolles, 1976.
6. Jean Lemale, *Heat Pumps*, 2nd Edition, DUNOD, Paris, 2012, 2014.

Semester: 3
Teaching Unit: UEF 2.1.2
Subject 2: Multiphase Reactors and Bioreactors
Total Hours (VHS): 67h30 (Lecture: 3h00, Tutorial/Practical Work: 1h30)

Credits: 6
Coefficient: 3

Teaching Objectives:

- The student will acquire knowledge regarding the operation of heterogeneous multiphase reactors such as absorbers and catalytic reactors.
- The student will acquire the basic concepts necessary for the design and analysis of bioreactors at an industrial scale.

Recommended Prior Knowledge:
Basic knowledge of homogeneous reactors, chemical kinetics, transport phenomena, and microbiology is recommended.

Course Content:

Part 1: Multiphase Reactors

Chapter 1: Two-Phase (Fluid–Fluid) Reactors

- Effect of chemical reaction on mass transfer (Two-film theory; Pseudo-first-order reaction – Hatta number (Ha); Fast reaction regime – Acceleration factor E; Instantaneous reaction regime – E vs Ha diagram).
- Calculations for biphasic reactors (Batch reactors, Plug-flow reactors, Continuous stirred-tank reactors).

Chapter 2: Fluid–Solid Catalytic Reactors

- Intra-particle diffusion (Thiele modulus; Effectiveness factor), effectiveness and external mass transfer (Effect of catalyst particle diameter; External mass transfer).
- Influence of internal diffusion on reaction (Weisz–Prater criterion).
- Influence of external mass transfer on reaction (Mears criterion).
- Fixed-bed reactors; Fluidized-bed reactors.

Part 2: Bioreactors

I. Introduction

- Review of basic microbiology, biochemistry, and molecular biology knowledge necessary for bioreactor calculations.

II. Modeling Reaction Rates in Biological Systems

- Microbial kinetics: Monod model, enzyme kinetics, enzymatic reaction inhibition.

III. Design and Analysis of Bioreactors

- Types of bioreactors, basic concepts.
- Batch bioreactors, Continuous stirred-tank reactors, Plug-flow bioreactors.
- Comparison of batch and continuous bioreactors.

IV. Mass Transfer in Bioreactors

- Aeration: Gas–liquid mass transfer.
- Agitation: Mass transfer by forced convection.

Assessment Method:

- Continuous assessment: 40%
- Final exam: 60%

Recommended References:

1. Roustan M., *Gas/Liquid Transfer in Water Treatment and Gaseous Effluent Processes*, Tec & Doc Lavoisier, Paris, 2003, ISBN: 2-7430-0605-6
2. Schweich D., *Chemical Reaction Engineering*, Tec & Doc Lavoisier, 2001, ISBN: 2-7430-0459-2
3. R. Missen, C. Mims, B. Saville, *Chemical Reaction Engineering and Kinetics*, John Wiley & Sons, New York, 1999
4. O. Levenspiel, *Chemical Reaction Engineering*, 3rd edition, John Wiley & Sons, New York, 1998, ISBN: 0471225424X
5. J. Villermaux, *Chemical Reaction Engineering: Design and Operation of Reactors*, 2nd edition, Tec & Doc Lavoisier, Paris, 1993, ISBN: 2-85206-132-5
6. B. Atkinson & F. Mayituna, *Biochemical Engineering and Biotechnology Handbook*, MacMillan, 1991, ISBN: 978-033342-4032
7. G. Froment & K.B. Bischoff, *Chemical Reactor Analysis and Design*, John Wiley & Sons, New York, 1979

Semester: 3
Teaching Unit: UEM 2.1
Subject 1: Laboratory Work – Biological Wastewater Treatment / Bioreactors
Total Hours (VHS): 22h30 (Practical Work: 1h30)
Credits: 2
Coefficient: 1

Teaching Objectives:

- Apply the theoretical concepts acquired in lectures.

Recommended Prior Knowledge:

- Basic knowledge of biochemistry, microbiology, and process engineering.

Course Content:

1. **Characterization of Wastewater:** COD, BOD_5, TOC, biogenic elements, toxic elements.
2. **Degradation in a Cascade Bioreactor.**
3. **Monitoring an Activated Sludge Reactor:** Determination of operating conditions.
4. **Monitoring the Efficiency of Biological Treatment:**
    - Characterization of sludge settleability: settling curve and sludge volume index.
    - Microscopic and macroscopic observation of activated sludge and diagnosis of malfunctions.

Note: It is recommended to perform at least six laboratory sessions, selected from the different groups, depending on available resources.

Assessment Method:

- Continuous assessment: 100%.

Semester: 3
Teaching Unit: UEM 2.1
Subject 2: Process Intensification
Total Hours (VHS): 22h30 (Lecture: 1h30)
Credits: 2
Coefficient: 1

Teaching Objectives:

1. Understand the principles of process intensification.
2. Apply intensification techniques to various processes.

Recommended Prior Knowledge:

- Mass and heat transfer, catalysis, reactors, unit operations.

Course Content:

Chapter 1: Fundamentals of Process Intensification

- Definitions, principles, and applications of process intensification (PI).
- Implementation of process intensification: equipment-based and method-based approaches.

Chapter 2: Equipment for Process Intensification

- Microreactors: Oscillatory baffle reactors, Rotating disk reactors.
- Centrifugal absorbers.
- Rotating packed columns.
- Examples of applications of these equipment in various processes.

Chapter 3: Methods for Process Intensification

- Multifunctional reactors (Reactive distillation, Membrane reactors).
- Hybrid separations (Membrane–absorption, Membrane–distillation).
- Examples of applications of these different methods.

Chapter 4: Alternative Energy Sources

- Solar energy, Ultrasound, Microwaves.

Chapter 5: Other Methods of Process Intensification

- New solvents (Supercritical fluids, Ionic liquids).
- Examples of applications of these solvents.

Assessment Method:

- Continuous assessment: 40%
- Final exam: 60%

Recommended References:

1. Stanckiewicz, A., and Moulijn, M., *Re-engineering the Chemical Processing Plant – Process Intensification*, Marcel Dekker, Inc., New York, 2003.

Semester: 3
Teaching Unit: UEM 2.1
Subject 3: Treatment of Contaminated Soils
Total Hours (VHS): 22h30 (Lecture: 1h30)
Credits: 2
Coefficient: 1

Teaching Objectives:
Sites contaminated by pollutant infiltration related to industrial operations pose risks to surface and groundwater, as well as to land use for habitation, agriculture, or industrial activities. This course aims to familiarize students with the various existing techniques for decontaminating sites polluted by different organic and inorganic compounds.
Recommended Prior Knowledge:
(Not specified, but basic knowledge in environmental engineering, chemistry, or soil science is implied.)
Course Content:
Introduction
Chapter I: Soil – Formation, Properties, and Rehabilitation

- Soil formation, soil types, properties (physical, chemical, biological), chemical, physical, and microbiological analysis of polluted soils.
- Soil contaminants and pollutants: organic and inorganic (characteristics and properties).
- Implementation techniques and regulations.

Chapter II: Physico-Chemical Methods

- Soil washing (leaching), chemical oxidation and reduction, stabilization/solidification, venting, containment (covering and sealing, vertical confinement, hydraulic trap).

Chapter III: Thermal Methods

- Thermal desorption (pyrolysis), incineration, vitrification.

Chapter IV: Biological Methods

- Phytoremediation, enhanced biodegradation, monitored natural attenuation, biopiles, composting.

Assessment Method:

- 100% Final Exam

Recommended References:

1. Jeff Kuo, *Practical Design Calculations for Groundwater and Soil Remediation*, 2014.
2. Khan Towhid Osman, *Soil Degradation, Conservation and Remediation*, 2014.
3. Marc Pansu, Jacques Gautheyrou, *Handbook of Soil Analysis: Mineralogical, Organic and Inorganic Methods*, Springer, 2006.
4. John Pichtel, *Fundamentals of Site Remediation: For Metal and Hydrocarbon-Contaminated Soils*, 2007.
5. Helmut Meuser, *Soil Remediation and Rehabilitation: Treatment of Contaminated and Disturbed Land*, 2013.
6. Rainer Stegmann, Gerd Brunner, Wolfgang Calmano, Gerhard Matz, *Soil Treatment of Contaminated Soil*, Springer, 2001.

Semester: 3
Teaching Unit: UEM 2.1
Subject 4: Experimental Design (Design of Experiments)

Total Hours (VHS): 37h30 (Lecture: 1h30, Practical Work: 1h00)
Credits: 3
Coefficient : 2

Teaching Objectives:
Enable students to master experimental manipulations and make results more meaningful.
Recommended Prior Knowledge:
Basic knowledge of mathematics.
Course Content:
Chapter 1: General Introduction and Factorial Designs
1. Introduction
2. What is a design of experiments
3. Study domain and response surface
4. Factors
5. Concept of interaction
6. Concept of model and multiple linear regression
7. Full 2^k factorial design
   - 7.1 Example of effect calculation
   - 7.2 Graphical representation of effects
   - 7.3 Matrix form – Multilinear regression
8. Application example

Chapter 2: Significance Tests and Model Validation
1. Introduction
2. Experimental errors
3. Significance tests of effects
4. Confidence intervals of model effects
5. Analysis of variance (ANOVA) – Linear model validation
   - 5.1 The ANOVA table
   - 5.2 Coefficient of determination and correlation coefficient
6. Application example

Chapter 3: Fractional Designs
1. Introduction
2. Design of a fractional factorial design
3. Analysis of fractional designs
4. Application example
5. Other designs: Plackett–Burman and Taguchi designs

Chapter 4: Response Surface Designs
1. Introduction
2. Concept of response surface and isoresponse curves
3. Designs for second-order models
   - 3.1 Box–Behnken design
   - 3.2 Central composite design
4. Quality and optimality criteria of an experimental design
   - 4.1 Calculation of optimal designs
5. Application example of response surface designs

Chapter 5: Mixture Designs
1. Introduction
2. Geometric representation of mixtures
3. Study domain in mixture designs
4. Mathematical models of mixtures
5. Analysis of a mixture design
6. Application example
7. Mixture designs and experimental designs: mixed designs

Applications:
- Introduction to Minitab software + obtaining coefficients of a full factorial design, graphical representation of main effects and interactions + ANOVA.
- Fractional factorial designs in Minitab

- Optimization using response surface designs (Box–Behnken + Central Composite)
- Use of mixture designs

Assessment Method:

- Continuous assessment: 40%
- Final exam: 60%

Semester: 3
Teaching Unit: UET 2.1
Subject 2: Chemical Reverse Engineering
Total Hours (VHS): 67h30 (Lecture: 1h30, Tutorial and/or Practical Work: 1h30)
Credits: 2
Coefficient: 2

Teaching Objectives:
Train the student in:

- Competitive intelligence.
- Quality approach (product quality control at a supplier, ensuring traceability and compliance analysis).
- Understanding and anticipating various phenomena (premature aging, product reactivity, structure–property relationships).
- Substitution of raw materials (shortages or strategic changes).
- Product optimization.
- Obtaining data for regulatory compliance.
- Intellectual property protection (checking patent infringements, unfair competition, etc.).

Recommended Prior Knowledge:

- Physico-chemical analysis methods (spectroscopy, microscopy, thermal analysis, etc.).

Course Content:

Chapter 1: Introduction to Chemical Reverse Engineering (RE)

- 1.1 History, legal and ethical issues of RE
  - Definitions and scope (hardware, software, processes, etc.)
  - Product design objectives, constraints influencing the product, target market, how the product works, and rationale behind design decisions.
- 1.2 Methods and applications
  - Chromatography: separate and identify mixture components
  - Spectroscopy: identify and quantify chemical bonds and elements
  - Microscopy: examine microstructure
  - Thermal analysis: study thermal properties
  - Rheology: study mechanical properties over time and temperature
- 1.3 Fields of application
  - Polymers, paints, inks, powders, ceramics, composites, packaging
  - Pharmaceuticals
  - Food industry
  - Cosmetics
  - Petrochemicals
- 1.4 Cases where reverse engineering is not possible
  - Complex formulations, lack of equipment, legal restrictions, safety issues, degradation

Chapter 2: General Methodology

- 2.1 Inverted pyramid approach:
  - 2.1.1 Global product analysis (documentary evaluation)
  - 2.1.2 Superficial analysis (solubility, chemical reactivity, fillers, number of compounds, molecular size)
  - 2.1.3 Specific analysis of individual compounds (isolation, identification, and qualification via chromatography, NMR, elemental analysis like SEM, EDX)
  - 2.1.4 Quantification of isolated species (chromatography, NMR, gravimetric techniques)
  - 2.1.5 Application examples: epoxy resins, phenolic resins, paints, shampoos, medical devices

Chapter 3: Reverse Engineering Process

- 3.1 Hypothesis on the manufacturing process
    - Reconstruct manufacturing steps from chemical composition (temperature, pressure, catalysts, order of reagent addition, reaction and purification conditions)
- 3.2 Modeling and simulation
    - Use chemical simulation software (Aspen Plus, ChemCAD) to validate hypotheses
    - Evaluate thermodynamic and kinetic equilibria
- 3.3 Experimental reproduction
    - Laboratory tests to verify formulation/process hypotheses
    - Adjust parameters based on results
- 3.4 Optimization
    - Improve process (yield, cost, environmental impact)
    - Develop equivalent or improved formulations (generic, patentable alternatives)

Chapter 4: Generic Pharmaceutical Form Development

- 4.1 Research and formulation
- 4.2 Bioequivalence testing
- 4.3 Toxicological, pharmacological, and clinical studies
- 4.4 Marketing authorization (MA) application
- 4.5 Quality control

Chapter 5: Polymer Development Techniques

- 5.1 Sample acquisition and preparation
- 5.2 Physical and chemical characterization (microscopy, spectroscopy, thermal analysis, etc.)
- 5.3 Formulation and reconstruction
- 5.4 Validation and optimization
- 5.5 Advantages of reverse engineering in polymer development (product reproduction, improvement, new product development, cost reduction, understanding competitors' products)

Chapter 6: Reverse Engineering of a Commercial Liquid Detergent

- Stepwise approach: sampling, physico-chemical analysis, component identification and quantification, formulation hypothesis, lab reproduction, adjustments and testing, final formulation optimization

Chapter 7: Analysis of a Multigrade Engine Oil (5W-30)

- Objective: understand chemical composition and technical properties to reproduce equivalent lubricants, identify additives, and develop comparable or improved products
- Steps: sample preparation, physico-chemical analyses (viscosity, VI, flash/freezing point, spectrometry), composition identification, formulation reconstruction, validation tests (tribology, engine simulation, bench testing), final formulation optimization

Assessment Method:

- Technical lab work: 30%
- Mini reverse engineering project (report + presentation): 40%
- Final exam (MCQ + case study): 30%
- Total: Final exam 60%, continuous assessment/lab TP: 40%

References:

- Jacques Villermaux, *Chemical Reaction Engineering: Design and Operation of Reactors*, Tec & Doc, 1993
- Daniel Schweich, *Chemical Reaction Engineering*, Tec & Doc, 2001
- Gilbert F. Froment & Kenneth B. Bischoff, *Chemical Reactor Analysis and Design*, Wiley, 2010
- Searson, D.P., Willis, M.J., & Wright, A., *Reverse Engineering Chemical Reaction Networks from Time Series Data*, 2014
- Marote, P., Martin, M., Bonhomme, A., Lantéri, P., & Clément, Y., *Artificial Intelligence for Reverse Engineering: Application to Detergents Using Raman Spectroscopy*, 2023
- *Techniques de l'Ingénieur, Chemical Processes: Complete Dossier*

Teaching Unit: UET 2.1
Subject 1: Literature Review and Thesis Design
Total Hours (VHS): 22h30 (Lecture: 1h30)
Credits: 1
Coefficient: 1

Teaching Objectives:
Provide students with the tools necessary to research and utilize relevant information effectively for their final-year project. Guide them through the stages leading to the writing of a scientific document. Emphasize the importance of clear communication and teach students how to present their work rigorously and pedagogically.

Recommended Prior Knowledge:

- Writing methodology
- Presentation methodology

Course Content:

Part I – Literature Review:

Chapter I-1: Defining the Subject (2 weeks)

- Title of the subject
- List of keywords
- Gather basic information (specialized vocabulary, term definitions, linguistic meaning)
- Identify the information needed
- Assess prior knowledge in the field

Chapter I-2: Selecting Information Sources (2 weeks)

- Types of documents: books, theses, dissertations, journal articles, conference proceedings, audiovisual materials
- Types of resources: libraries, Internet, etc.
- Evaluate the quality and relevance of information sources

Chapter I-3: Locating Documents (1 week)

- Research techniques
- Search operators

Chapter I-4: Processing Information (2 weeks)

- Organize work
- Formulate initial questions
- Summarize selected documents
- Connect different parts
- Final plan of the literature review

Chapter I-5: Bibliography Presentation (1 week)

- Bibliography formats: Harvard, Vancouver, mixed systems
- Document presentation
- Source citation

Part II – Thesis Design:

Chapter II-1: Thesis Plan and Stages (2 weeks)

- Define and delimit the subject (summary)
- Problem statement and objectives
- Other useful sections (acknowledgements, abbreviations, etc.)
- Introduction (written last)
- Literature review
- Hypothesis formulation
- Methodology
- Results
- Discussion
- Recommendations
- Conclusion and perspectives
- Table of contents

- Bibliography
- Appendices

Chapter II-2: Writing Techniques and Standards (2 weeks)

- Formatting: numbering of chapters, figures, tables
- Cover page
- Typography and punctuation
- Writing style: scientific language, grammar, syntax
- Spelling; improving overall linguistic competence in comprehension and expression
- Data management: save, secure, and archive information

Chapter II-3: Workshop – Critical Review of a Manuscript (1 week)

Chapter II-4: Oral Presentations and Defenses (1 week)

- How to present a poster
- How to deliver an oral presentation
- Thesis defense

Chapter II-5: How to Avoid Plagiarism (1 week)

- Proper citation of formulas, phrases, illustrations, graphs, data, statistics
- Paraphrasing
- Provide complete bibliographic references

Assessment Method:

- Final exam: 100%

Recommended References:

1. M. Griselin et al., *Guide de la communication écrite*, 2nd edition, Dunod, 1999
2. J.L. Lebrun, *Practical Guide to Scientific Writing: How to Write for the International Scientific Reader*, EDP Sciences, 2007
3. A. Mallender Tanner, *ABC of Technical Writing: Instructions and Online Help*, Dunod, 2002
4. M. Greuter, *Writing Your Thesis or Internship Report Well*, L'Etudiant, 2007
5. M. Boeglin, *Reading and Writing at University: From Chaos of Ideas to Structured Text*, L'Etudiant, 2005
6. M. Beaud, *The Art of the Thesis*, Editions Casbah, 1999
7. M. Beaud, *The Art of the Thesis*, La Découverte, 2003
8. M. Kalika, *Master's Thesis Guide*, Dunod, 2005