UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Sustainable Chemistry

2324-1-F7501Q104

Aims

General aims
The course is aims at providing the knowledge and methodological bases to know and understand the principles that define sustainable and / or green chemistry in all the aspects related to this topic. The course presents underlying concepts, i.e., the 12 Principles of Green Chemistry, and their manifestations in the real world, in form of European regulations like the REACH and in form of processes and modern practices in research and development as well as in production within areas that are based on or comprise chemical transformations. The impact of sustainability on chemical processes and production is discussed introducing and applying sustainability parameters like atom economy or carbon footprint. Quantification of such parameters and estimating their economic impact on chemical processing are done in form of hands-on life cycle assessments applying standard simulation tools used in the area.

Knowledge and understanding
At the end of the course the student will have a fundamental understanding of:
• The main parameters to be evaluated to define a low environmental impact process.
• The correct definitions of green chemistry.
• The main indicators of environmental sustainability;
• The fundamentals of environmental reactivity of chemical compounds.
• The connections between sustainable and/or green processes and the (bio-based) circular economy.
• The scientific challenges connected to moving from an oil-based economy to a bio-based economy.
• The difference between sustainable processes, green processes and processes that are both sustainable and green.
• European legislative frameworks connected to the fields of sustainable chemistry
• The fundamentals of life cycle analysis.

Applying knowledge and understanding
At the end of the course the student will be able to:
• apply the concepts of green chemistry learned in the course that form the basis of sustainable development according to the UN 2030 agenda.

• judge whether a process qualifies as a green and/or sustainable process.
• describe means of sustainable processing.
• understand the impact of concepts like lab-on-a-chip and model organisms for sustainability.
• calculate some of the main environmental sustainability indicators.
• calculate mass and energy flows in the life cycle analysis of a product or process and estimating the impact of sustainability on these.

Making judgements
At the end of the course the student will be able to:
• apply the acquired knowledge in various contexts.
• transfer the concepts and approaches introduced in a certain context to connected fields.
• elaborate the concepts of sustainable and green processing discussed in the course.
• analyze the phases of the life of a product or a process;
• critically evaluate the results obtained from the application of the models;
• identify possible interventions to reduce the impacts.

Communication skills
At the end of the course the student should be able to
• analyse a chemistry-related problem in a clear and concise way.
• explain orally with a suitable language the objectives, the procedures and the results of the elaborations carried out.

Learning skills
At the end of the course the student should be able to different from those presented during the course, and to understand the topics covered in the scientific literature concerning the sustainability issue.

Contents

Contents
• The concepts of green chemistry and sustainable chemistry, their commonalities and their differences.
• The concept of biorefinery for the production of sustainable raw materials.
• Responsible and sustainable use of non-renewable resources such as metals, aspects of recycling within a circular economy.
• The reactivity of chemical compounds in the environment.
• Sustainable processes for the production of standard materials, platform chemicals and performance materials.
• Sustainable processes in the field of chemistry for the production of fine chemicals.
• Sustainability in the field of nanomaterials.
• Regulatory aspects like REACH, concerned with sustainability and control of chemical production and exploitation and use of single chemicals and mixtures.
• Aspects on sustainable energy.
• Indicators of sustainability, means for quantifying sustainability.
• Life cycle analysis and application of sustainability parameters.

Detailed program

Detailed program
• Evolution of sustainability in industrial syntheses on the basis of selected examples.
• Evolution of the concepts of green chemistry and sustainable chemistry.
• Common points and differences between green chemistry and sustainable chemistry.

• Description of the main renewable resources suitable for substituting oil as main raw material source for the chemical industry with particular reference to the structure of lignocellulosic materials.
• The concept of bio-refinery with examples and applications in Italy and Europe, also in view of the circular economy.
• Synthesis of chemicals from renewable sources with sustainable processes.
• Sustainable and / or green concepts for performing chemical reactions, for example flow chemistry.
• Sustainable processes in chemistry-related fields: point-of-care-devices, organ-on-a-chip, model organisms.
• Synthesis and advantages of sustainable nanomaterials, and associated regulatory aspects.
• Synthesis of new biodegradable and non-biodegradable materials starting from renewable sources with sustainable processes.
• Recycling, downcycling and upcycling as tools for the circular economy.
• The integration of sustainable processes within the circular economy and their construction.
• Description of the challenges associated with the recycling and reuse of various materials, including precious metals, concept of urban mining.
• Distribution of elements across various environments using (anthro)biogeochemical cycles.
• Reactivity of compounds in the atmosphere and consequences for environment, health and cultural heritage.
• Reactivity of compounds in water, including surface waters and oceans.
• Life time and half life of the compounds in the environment.
• Sustainable mining activities.
• Regulatory tools, especially REACH, for implementing sustainability and environmental compatibility in socio-economic contexts and legislation.
• Sustainability indicators: Human development index, Index of Sustainable Economic Welfare.
• Environmental sustainability indicators: emergetic analysis, ecological footprint.
• Life cycle analysis: history, objectives,
• LCA phases: of an analysis, inventory (primary, secondary and tertiary data, allocation), impact assessment (midpoint and endpoint impact categories, classification, characterization, normalization, weighing).
• Case studies.

Prerequisites

Prerequisites
• Basic knowledge of organic and inorganic chemistry and biology.
• Basic notions of thermodynamics.

Teaching form

Teaching modes
• 8 CFUs of theoretical lessons in the classroom (64 hours).
• 4 CFU of exercise sessions (40 hours) to learn using the most used software in LCA.
• Case studies, to be prepared during the lessons by the students in groups according to various schemes, with final discussions together.
• In the event of a COVID-19 emergency, the course will take place via remote lessons which will also be recorded and uploaded to the e-learning webpage connected to the course.

Textbook and teaching resource

• M. Aresta, A. Dibenedetto, F. Dumeignil
Biorefineries – An introduction
De Gruyter
• P.T. Anastas
Green Chemistry - Theory and Practice
Oxfod University Press
• B. Marchesini, M. Monari
Il regolamento REACH
Maggioli Editoreslides
• slides
• notes shown during lectures and additional material on selected topics, i.e., scientific articles, made available on the e-learning website of the course.

Semester

I semester (October - January)

Assessment method

The final exam consists of a single oral exam at the end of the course, with a score between 18-30 / 30, which comprises the discussion of various topics covered in the course, with an emphasis also on the connections between concepts and processes, such as to arrive at a critical evaluation of work from the point of view of sustainability in chemistry as a whole.

Assesment will be based on the following criteria: (1) knowledge and understanding; (2) ability to connect different concepts; (3) autonomy of analysis and judgment; (4) ability to correctly use scientific language.

Given the experimental nature of the hands-on experinece using different LCA tools, the concerned module offers a final test that can be validated in the final exam for the part of course concerned with the LCA. N.B.: This written test remains valid for the entire academic year in which the course was carried out. In the event that the student does not take the written exam in progress or opts to take the exam in another academic year, the LCA analysis part is again part of the oral exam program.

Office hours

Always, after scheduling an appointment via phone or e-mail.

Sustainable Development Goals

QUALITY EDUCATION