UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

COURSE SYLLABUS

Laboratory of Urban Mining - Opportunities and Limits

2627-1-F7603Q023

Aims

This laboratory course introduces students to the emerging field of urban mining, exploring how waste can be transformed into valuable resources. It combines theoretical foundations with practical experiments to examine the opportunities and limits of waste valorization within a circular economy framework. The course also aims to demonstrate how what is commonly considered waste, or even toxic waste, can be recycled as secondary raw material in a sustainable way.
The laboratory course also aims at providing the knowledge and the working principles behind case studies related to relevant emerging and real industrial activities and projects of implementation of circularity, clean technology and climate technology, with particular emphasis on carbon capture utilization and storage.

Knowledge and understanding
At the end of the course the student will have a fundamental understanding of:
• The fundamental concepts of urban mining and waste-to-wealth strategies.
• Techniques for waste characterization and material recovery.
• The technical, environmental, and economic challenges inherent in transforming waste into resources.
• Relevant regulatory frameworks and sustainability indicators in the context of urban mining.
• Basic concepts of mineralogy and related characterization techniques.
• Case studies demonstrating how waste can be recycled as secondary raw material in a sustainable way in a perspective of a circular economy.
• Knowledge and the working principles behind case studies related to relevant emerging and real industrial activities and projects of implementation of circularity, clean technology and climate technology, with particular emphasis on carbon capture utilization and storage.

Applying knowledge and understanding
At the end of the course the student will be able to:
• Design and execute laboratory experiments focused on recovering valuable materials from waste streams.
• Apply analytical methods to evaluate the efficiency and sustainability of recovery processes.
• Quantify key environmental and economic indicators related to urban mining practices.
• Assess mass and energy balances in relation to all their steps.

Making judgements
At the end of the course the student will be able to:
• Critically assess urban mining techniques and experimental outcomes.
• Propose improvements and innovative solutions to optimize recovery processes while considering technical, environmental, and economic constraints.
• Evaluate case studies to discern the real-world applicability of waste-to-wealth strategies.

Communication skills
At the end of the course the student should be able to:
• Clearly present experimental procedures, results, and analyses.
• Articulate the benefits and limitations of urban mining in both written reports and oral presentations.
• Engage in informed discussions on sustainable waste management practices.

Learning skills
At the end of the course the student should be able to:
• Demonstrate independent research and critical thinking through hands-on experiments and data analysis.
• Show collaborative problem-solving and group work to tackle real-world challenges in urban mining.
• Show continuous development of technical skills necessary for innovative environmental practices.

Contents

• Introduction to Urban Mining: Concepts, definitions, and relevance.
• Waste Characterization: Techniques for chemical and physical analysis.
• Technologies for Material Recovery and Recycling.
• Environmental Impacts: Sustainability indicators and life cycle assessment in urban mining.
• Regulatory and Economic Aspects: Overview of policies and market drivers.
• Practical Laboratory Sessions: Experiment design, execution, and data interpretation.
• Case Studies: Successes and challenges in turning waste into wealth.
• Introduction to minerals and mineral resources.
• Introduction to material characterization techniques.
• Thermal deactivation of asbestos cement and recycling.
• Rare earth elements for green technologies.
• From waste to secondary raw materials.
• The pathways of carbon capture.
• The pathways of carbon utilization.
• Focus on mineral carbonation.

Detailed program

• Overview of Urban Mining and Waste-to-Wealth Concepts.
• Waste Characterization: Methods for assessing waste composition.
• Technologies in Urban Mining: Recovery and recycling processes.
• Environmental and Economic Evaluation of Recovery Techniques.
• Laboratory Practicals: Setting up experiments for material recovery.
• Data Analysis and Process Optimization.
• Case Studies: Examining real-world opportunities and limitations.
• Introduction to minerals and mineral resources.
• Raw materials for the ceramic industry.
• Cement minerals.

• Common inorganic fillers.
• Introduction to material characterization techniques.
• Thermal deactivation of asbestos cement and recycling.
• Cost-benefits analysis and life cycle assessment of asbestos deactivation and recycling.
• Ecotoxicological tests on deactivated asbestos cement.
• Rare earth elements for green technologies.
• REE ore minerals.
• The contribution of mineralogy to REE exploration, exploitation, beneficiation and recycling.
• From waste to secondary raw materials.
• Red muds from the alumina production: the case of red mud from Portovesme (Sardinia, Italy).
• From high-volume industrial waste to new ceramic material.
• Flotation sludges from precious metal recovery processes.
• Stearate from the metal wire industry: recycling in ceramics, mortar and polymers.
• The pathways of carbon capture.
• Direct air capture: Absorption-based carbon capture, hot potassium carbonate, amine-based absorbers, electrodialysis.
• Discussion of industrial realities of direct air capture: Carbonco, Catacarb, Mega.
• Ocean Alkalinity Enhancement, Direct ocean capture. Discussion of industrial realities.
• Limenet, SeaO2, ResourSEAs.
• Geological sequestration.
• Discussion of industrial realities for geological sequestration: CarbFix.
• Determination of the acidity of an acidic solution by gravimetry with sodium bicarbonate – determination of the capture ability of basic solutions.
• The pathways of carbon utilization.
• Electrochemical conversion into chemicals and fuels.
• CO2 battery.
• Focus on mineral carbonation.
• Reactivity of Mg- and Ca-bearing minerals and their conversion into stable and valuable carbonate phases.
• The Anticarb project.

Prerequisites

• Basic knowledge of chemistry.
• Basic knowledge of materials science.
• Familiarity with environmental science concepts is recommended.
• Fundamental laboratory skills.
• Experience in data analysis.

Teaching form

6 CFU of mixed didactics in the classroom (60 hours):
• 14 two-hour lectures, in person, Delivered Didactics;
• 2 two-hour practical sessions (quiz), in person, Interactive Teaching;
• 2 two-hour practical sessions with seminars, visits to laboratories (virtually or in person), Interactive Teaching;
• 3 two-hour experimental sessions, in person, Interactive Teaching;
• 1 two-hour lecture with virtual and on-site visit and illustration of the analytical laboratories of Anticarb, Interactive Teaching;
• 6 two-hour experimental sessions and collaborative sessions, in person, Interactive Teaching.

Attendance to lectures and interactive exercises is highly recommended.

Textbook and teaching resource

• Selected scientific articles, reports, and case studies on urban mining and waste management.
• Recommended reading: “Urban Mining: Recycling Metals from Waste” (or equivalent current literature).
• Laboratory manuals, online resources, and additional materials provided during the course.
• Lecture notes provided by the lecturer.
• Research articles and book chapters provided by the lecturer.
• On-line material.

Semester

II semester (March - June)

Assessment method

At the end of each module, an individual assessment needs to be passed. Students are invited to consult the syllabi of the modules for additional information.

The final oral exam for the laboratory course as a whole comprises the discussion of various topics covered in the three modules, with an emphasis also on the connections between concepts and tools, such as to arrive at a critical evaluation of the laboratory course topics as a whole.

The final score will be between 18/30 and 30/30 *cum laude*, based on the overall assessment considering 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.

Office hours

Please refer to the indications provided in the syllabi of the modules.

Sustainable Development Goals

QUALITY EDUCATION | INDUSTRY, INNOVATION AND INFRASTRUCTURE | SUSTAINABLE CITIES AND COMMUNITIES | RESPONSIBLE CONSUMPTION AND PRODUCTION