UNIVERSITÀ
DEGLI STUDI DI MILANO-BICOCCA

SYLLABUS DEL CORSO

Chimica dell'Atmosfera

2627-2-F7503Q020

Aims

Objectives

The student acquires knowledge of the chemical composition of the atmosphere, its changes, and the reactivity of gaseous and particulate matter (and their mutual interaction) in both natural and man-made environments, both indoors and outdoors.
The student acquires knowledge of the impact of air quality on:

- health and ecosystems
- climate
- cultural heritage
- electronic systems

Knowledge and Understanding (Dublin Descriptor 1)
At the end of the course, the student understands:
The main reactions of compounds present in the atmosphere, and radical reactions.
Stratospheric and tropospheric ozone formation and removal processes
The formation, evolution, deposition, and chemical composition of atmospheric particulate matter (PMx)
The interaction between the gaseous and particulate phases
The transport and reactivity processes of chemical compounds in the atmosphere
The effects of air pollutants on climate, electronic products, and cultural heritage
The processes that regulate environmental concentrations of air pollutants in indoor/outdoor environments and their relationships and effects on human health

Furthermore, students acquire, review, and strengthen their knowledge regarding:

- the atmospheric environmental influences on the biology of living organisms and humans, especially regarding exposure and dose-response; the molecular and cellular mechanisms of the toxic action of air pollutants; the principles of risk assessment; and frontier research lines (micro- and nanoplastics);

- distributions between different environmental compartments and the mechanisms of accumulation, transport, and transformation. of chemical compounds in environmental matrices
- standards and procedures for predicting and assessing the various impacts of air pollutants on the environment (in terms of use in Environmental Impact Assessments (EIA), Strategic Environmental Assessments (SEA), and Integrated Environmental Authorizations (IPA)), tools for managing public relations in preventive environmental assessments; key environmental law regulations (European and national) regarding atmospheric chemistry
- the economic impact of air pollution related to the concept of (negative) externalities, public goods, and the monetary valuation of pollution
- life cycle assessments (LCA) involving atmospheric pollutants from an environmental sustainability perspective
- the classification of air pollutants among climate drivers and their impacts on natural and human-made systems, as well as the feedback mechanisms inherent in atmospheric compounds within the Earth system; Atmospheric processes and the physical laws that regulate them, the importance of adaptation and mitigation measures
- The use of some multivariate analysis techniques in the service of atmospheric chemistry
- The difference between equilibrium and steady state and their application domains in atmospheric sciences
- Know the potential of remote sensing for estimating chemical components in the atmosphere
- Master the interdisciplinary connections between the three scientific areas

Applied Knowledge and Understanding (Dublin Descriptor 2)
At the end of the course, the student will be able to:

- Calculate the lifetime and half-life of compounds present in the atmosphere and predict their reactivity, determine which anthropogenic air pollutants are persistent and toxic organic compounds, identify compounds with potential impact on other environmental compartments and on humans and ecosystems from a one health perspective, and identify strategies for controlling atmospheric pollutants
- Determine tropospheric ozone concentrations
- Determine the PMx concentrations and sources
- Determine target air pollutants requiring attention in an Environmental Impact Assessment
- Determine the mass and energy flows associated with air pollution and atmospheric transport processes
- Know how to apply legal regulation to protect the atmosphere (present and future), and foster critical thinking in identifying problems and developing related solutions
- Know how to critically analyze the evolution of atmospheric chemistry in response to evolving energy and environmental policies at the national and supranational levels
- Know how to assess the need for a multivariate approach to analyzing atmospheric data and evaluate the information that can be extracted from them
- Evaluate the spatio-temporal evolution of a chemical species in the atmosphere using equilibrium and/or the stability of non-equilibrium steady states
- Understand the chemical-physical aspects of climate change and critically interpret the interactions between various environments and climate change, with particular attention to the
- atmosphere
- Ability to access remote sensing resources for estimating atmospheric pollutants
- Ability to evaluate the interconnection between meteorology and pollutant concentrations
- Ability to make logical connections between topics in Atmospheric Chemistry and those in environmental sciences

Making Judgements (Dublin Descriptor 3)
At the end of the course, the student will be able to:

- Identify which chemical compounds present in the atmosphere can impact the environment and humans.
- Identify strategies for controlling air pollutants
- Examine the chemical and physical parameters of the atmosphere, assess the concentrations of air pollutants, and apply an appropriate scientific method to interpret data
- Define atmospheric transport processes

- Assess the impact of air pollution on health, ecosystems, climate, cultural heritage, and high-tech human-made artifacts
- Independently choose the most appropriate methodological, technological, or modeling approach to assess and solve problems related to atmospheric chemistry
- Ability to integrate atmospheric chemistry into an interdisciplinary framework (chemistry, biology, geology, ecology, physics, law, economics) to address complex environmental problems and the relationship between humans and the environment in the atmospheric sector
- Ability to critically analyze scientific literature and technical-regulatory documents
- Ability to independently evaluate policies, plans, and programs in the air sector (legal, economic, energy), including in terms of sustainability and the UN Agenda 2030
- Ability to independently develop the project and methodology for the final exam, critically evaluating the results obtained and integrating them with scientific literature.

Communication Skills (Dublin Descriptor 4)
At the end of the course, the student will be able to:

- Be able to clearly and concisely explain, with appropriate language, the main chemical reactions of anthropogenic and natural compounds and transport processes in the atmosphere.
- Be able to clearly and concisely explain, with appropriate language, the main effects of air pollution on humans, the environment, climate, cultural heritage, and electronic devices.
- Scientific communication skills in English at a B2 level, both verbally and in writing, in technical and scientific contexts.
- Ability to interact and collaborate with third parties.

Learning Skills (Dublin Descriptor 5)
At the end of the course, the student will be able to:

- Be able to apply acquired knowledge of atmospheric chemistry to determine tropospheric ozone concentrations of PMx. Understand the topics presented in the scientific literature on atmospheric chemistry, both past and present. Be able to apply the acquired knowledge to new areas, different from those covered in the course, independently integrating it with other sources of knowledge.
- Consult international scientific literature (including English), databases, and technical reports from research centers, local authorities, governments, and international organizations.
- Work both in groups and independently, using the scientific method as a working tool.

Ability to perform measurements and understand the data
Students will conduct laboratory measurements with cutting-edge scientific instrumentation on the chemical composition of the atmosphere, PM sampling, stack emissions, climate measurements, interaction with ambient humidity, and particle hygroscopicity.

Contents

The Atmospheric Chemistry course aims to provide students with a solid theoretical and practical foundation on the composition and chemical reactivity of our atmosphere, analyzing the dynamics governing the gaseous and particulate phases, both in natural contexts and within highly anthropized areas, with a broad focus on both outdoor and indoor environments. The core of the curriculum is an in-depth study of the impacts of air quality on crucial sectors such as human health and ecosystem stability, global climate change, the preservation of cultural heritage, and the integrity of electronic and technological systems.

From a knowledge perspective, the course leads students to master the main reactions of atmospheric compounds, with a specific emphasis on the complex radical reactions and the biochemical mechanisms that regulate the formation and destruction of ozone, both in the stratosphere and the troposphere. Particular attention is paid to atmospheric particulate matter, examining its chemical composition, formation processes, temporal and spatial evolution, as well as the deposition dynamics and constant interactions between the gaseous and solid or liquid phases of atmospheric particulate matter. These concepts are further enriched and strengthened through an interdisciplinary perspective, extending to the most recent lines of scientific research studying the emergence of global contaminants such as micro- and nanoplastics in the atmosphere.

The course provides the cognitive and methodological laboratory tools for the chemical analysis and measurement of compounds that regulate and determine air quality in both remote and anthropized environments, and their effects on the environment and humans, along with the ability to critically interpret the data.

Detailed program

The detailed program is presented here in bullet points, considering that it integrates basic notions with the latest advances in the scientific literature:

- Chemical composition of the atmosphere: macroconstituents and their temporal trends in the context of climate change
- The link between air pollution, thermodynamics, and economics
- Classes of atmospheric compounds. Primary contaminants, their inventory; secondary contaminants, their formation and transformation
- Italian and European regulations on air quality from present to future, both indoors and outdoors
- Equilibrium and Steady State
- Photochemically generated reactive oxygen species; radicals in the atmosphere. The oxidizing power of the atmosphere. Radical reactivity: initiation, propagation, termination
- Stratospheric ozone. Chemical reactions in the stratosphere. Contamination by gaseous organic compounds, CFCs, and organohalogenated compounds. HCFCs and regulation. HFCs and regulation. New and unexpected CFCs. Ozone depletion potential. The role of Polar Stratospheric Clouds (PSC).
- Ozone in the Troposphere. Local and global effects of chemical reactivity in the troposphere. Steady State of Ozone and NOx. Effects of volatile organic compounds (VOCs), temperature, and radiation on ozone steady state. Ozone isopleths. Effects on humans and the environment. Ozone and urban management: the role of green cities. Ozone trends, from past to future. Ozone and energy and vehicle transitions. Ozone and the unwanted COVID experiment. Ozone and examples in environmental impact assessments. Ozone formation potential and its use in policy decision-making.
- Gas-phase reactivity of VOCs: alkanes, alkenes, alkynes, aromatics, NOx, NOy, sulfur compounds (SO2 and DMS). Types of formation products and vapor pressure changes as a bridge to the particulate phase. Formation of carcinogenic intermediates, formation of greenhouse gases during atmospheric reactivity.
- Aerosols and atmospheric particulate matter: similarities and differences
- Evolution of particulate matter in the atmosphere: nucleation, coagulation, condensation, evaporation, deposition, hygroscopic activation (interaction with atmospheric humidity), and cloud formation. Primary and secondary, anthropogenic and natural origins. Combustive, desert, sea spray, and bioaerosol particulate matter in the atmosphere. Chemical composition of particles from their primary emission through their evolution in the atmosphere. Thermodynamic equilibrium with the gaseous phase. Heterogeneous reactivity in the liquid particulate phase. Particles as carriers of persistent compounds and as chemical reactors. Definition of PM10, PM2.5, and PM1. Differences between American and European technical regulations.
  Effects of air pollutants on the environment, cultural heritage, and human health.
- Meteorology and air pollution: interconnections, mixing layer, vertical profiles, and atmospheric reactivity (gases and particulates) along the vertical and during long-range transport
- Effects of atmospheric chemistry on climate: radiative forcing, aerosol optical properties, direct and indirect effects, cooling vs. warming, energy redistribution, and effects on regional and continental circulation. Applications of remote sensing to atmospheric chemistry and aerosol climate forcing
- Effects of atmospheric chemistry on humans. From concentration and dose to response and the calculation of years of life lost and/or lived with disabilities based on epidemiological data.

- Effects of atmospheric chemical composition on cultural heritage: exceptional case studies, including Leonardo da Vinci's "Last Supper" and Pellizza da Volpedo's "The Fourth Estate."
- Effects of atmospheric chemical composition on data centers and energy consumption. Connection with electronic resilience to weathering and induced corrosion
- Gas-phase and particulate measurement methodologies: theory and laboratory practice and associated reference standards
- Indoor and outdoor measurements of air pollutants in laboratory practice
- Sampling and analysis of the chemical composition of atmospheric particulate matter in the laboratory
- Analysis of laboratory data, national and international databases, data access and processing
- Modeling of aerosol hygroscopicity at thermodynamic equilibrium in the laboratory

Prerequisites

Prerequisites include knowledge and/or review of:

- environmental chemistry
- organic chemistry
- inorganic chemistry

Teaching form

- Lessons, 4 credits - 32 hours, in person, Delivered Didactics also by videoconferences and recorded

- Laboratory experiences, 2 credits - 20 hours, in person, Interactive Teaching

The course will be in English is required by the incoming foreign students

Textbook and teaching resource

The teaching material will be available on the e-learning platform. The official course slides will be in English.

Suggested reading:
Seinfeld, John H. ; Pandis, Spyros N., Atmospheric Chemistry and Physics - From Air Pollution to Climate Change (3rd Edition). John Wiley edition

Semester

first semester

Assessment method

Assessment is via an oral exam.

The exam consists of assessing the student's knowledge of atmospheric chemistry, with particular attention to voltaic organic compounds, stratospheric and tropospheric O?, atmospheric particulate matter, its formation and evolution.
The effects of air pollutants on the environment, climate, humanity, cultural heritage, and anthropogenic artifacts.

In the oral exam, the student will be assessed based on the following criteria: 1) knowledge and understanding; 2) connection of different concepts; 3) independent reasoning; 4) ability to use scientific language.

Grade out of 30: 18-30/30 with honors

Office hours

Prof. Luca Ferrero receives the students by appointment via e-learning or by email at
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Sustainable Development Goals

GOOD HEALTH AND WELL-BEING | SUSTAINABLE CITIES AND COMMUNITIES | CLIMATE ACTION