University of Zagreb

1. GENERAL INFORMATION				
1.1 Course teacher	Prof. Vesna Tomašić, PhD		1.6 Year of the study	2 (3. Semester)
1.2 Name of the course	Air Pollution and Control		1.7 ECTS credits	5
1.3 Associate teachers	Marin Kovačić, PhD Marina Duplančić, PhD Josipa Papac, mag. ing. oecoing.		1.8 Type of instruction (number of hours L + E + S + e-learning)	Total: 60 (L: 30, E: 15, S:15)
1.4 Study programme (undergraduate, graduate, integrated)	Graduate		1.9 Expected enrolment in the course	10
1.5. Status of the course	☐ mandatory	☒ elective	1.10 Level of application of e-learning (level 1, 2, 3), percentage of online instruction (max. 20%)	1

2. COUSE DESCRIPTION	
2.1. Course objectives	Introducing students to air pollution, air pollution control and legislation. Students will apply chemical engineering methodology necessary for design and sizing of process units and technological processes used in air pollution control, define key process parameters and develop mathematical models with the goal of optimizing process conditions and develop integrated processes for air pollution reduction and environmental engineering. The course includes design and sizing of process units for particulate removal and units for the removal of gaseous pollutants (VOC, NO_x, SO_2), for reduction of indoor, as well as outdoor pollution from stationary and mobile atmospheric emission sources.
2.2. Enrolment requirements and/or entry competences required for the course	Regular lecture attendance of all enrolled courses. Basic knowledge from fundamental and technical sciences, basic chemical engineering knowledge related to mass and energy balance, transfer of matter and energy, chemical engineering thermodynamics, fluid mechanics, unit processes and unit operations.
2.3. Learning outcomes at the level of the programme to which the course contributes	• Compile and apply advanced knowledge of natural and technical sciences, particularly chemical engineering and environmental engineering in solving scientific, professional and general social problems. • Correlate expert knowledge from chemistry, chemical engineering and material engineering with awareness of influence on society, economy and environment. • Utilise advanced laboratory procedures and instruments for synthesis of new products, create sustainable processes, and solve problems of water, air and soil pollution. • Apply different analytical techniques, analytical and numerical methods, as well as software tools in creative problem solving of engineering challenges, proposing sustainable technological solutions. • Optimise complete and sustainable technological processes using analysis and modelling aimed at waste minimization utilising the strategy of the closed cycle manufacturing.

	• Evaluate technological processes and products from the perspective of high functionality in different conditions and environmental effects. • Create a critical analysis, evaluation and interpretation of personal results, and compare them with existing data in scientific and expert literature
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	• define types pollutants according to phase, • define the mechanism of formation of solid and gaseous pollutants, • compare primary, secondary and integrated approach to air and environment protection, • analyse industrial processes according to types of pollution, • define the classification of industrial plants according to sources of pollution, • explain the classification of technological processes and units in relation to the phase of the pollutant, apply the correct method of separation and understand the roles of forces used in such processes, • explain how the size and dynamics of particles affect selection and sizing of particulate matter removal devices, • define and analyse the operation of particulate matter removal units, • define the similarities between adsorption and absorption processes, such as scrubbing/washing and stripping, • explain the basic principles of bioprocesses for waste gas treatment, • analyse the specificity of waste gas treatment from mobile sources.
2.5. Course content (syllabus)	Within the scope of this course, students will be introduced to basic terms and definitions related to pollution of air, pollution sources and sinks, the effects of pollution, mechanisms of pollutant formation, legislation and related subjects. Students will be introduced to sampling and analysis procedures of common and specific pollutants of indoor environments and the atmosphere. The focus will be on technological processes and units for air pollution reduction, accompanied by a detailed analysis of basic characteristics of such units and the development of skills necessary for sizing of such units and optimization of their operation. Basic knowledge will be applied to solving real-world engineering challenges through seminars and laboratory work. Research papers will encompass a defined issue, several proposed technical solutions in relation to current state-of-art, criteria of maximally permissible concentrations, economic aspects, specific requirements of certain processes, etc. The syllabus by week is as follows: **WEEK 1.** Introduction to the problem of air pollution: composition and structure of the atmosphere, a historic overview of pollution and its consequences. **WEEK 2.** Pollution of the atmosphere: pollution dispersion, legislation, sources and sinks, main groups of pollutants, monitoring and measuring of emissions. Seminar: application of commercially available software packages for the modelling of pollution dispersion and introduction to atmospheric prognostic models in use at the Croatian National Hydrometeorological Institute.

	WEEK 3. Mechanisms of pollutant formation, ways of solving problems in air pollution. Seminar: examples of preventive approaches to addressing air pollution issues. **WEEK 4.** Classification of technical processes and units in air pollution prevention, particulate removal, fluid particle dynamics. Seminar: calculation of concentration, emission factors, settling velocity, etc.. **WEEK 5.** Partial exam **WEEK 6.** Removal of particulates using mechanical separation methods, i.e.: gravity separators, cyclones, filters, electrofilters. Seminar: examples of particulate removal units and processes, calculation of particle diameter, particle size distribution functions **WEEK 7.** Gaseous and particulate removal by scrubbing. **WEEK 8.** Removal of gaseous pollutants by physical separation methods (adsorption and absorption). Seminar: examples of methods used for the removal of gaseous pollutants. **WEEK 9.** Removal of gaseous pollutants by condensation and membrane separation. **WEEK 10.** Partial exam **WEEK 11.** Chemical and biological treatment of exhaust gases. **WEEK 12.** Exhaust gas treatment from mobile sources. **WEEK 13.** Pollution of indoor atmosphere. **WEEK 14.** Decreasing of air pollution emission from industrial sources. **WEEK 15.** Partial exam. *Field work*: Visit to the Institute for Medical Research and Occupational Health – introduction to measurement methodologies and air quality monitoring. *Research papers:* reduction of emissions in: electric power production, oil and gas refining, inorganic chemical production (ammonia, acids and fertilizers), metallurgy, production of construction materials, etc. *Laboratory exercises*: Absorption of CO_2 – investigation of process parameter influence on the efficiency of CO_2 absorption; Catalytic oxidation of VOC in monolithic reactors; Catalytic reduction of NOx in monolithic reactors; Photocatalytic degradation of model VOC.		
2.6. Format of instruction:	☒ lectures ☒ seminars and workshops ☒ exercises ☐ online in entirety ☐ partial e-learning ☒ field work	☐ independent assignments ☐ multimedia and the internet ☐ laboratory ☐ work with mentor ☒ research paper (other)	2.7. Comments:

2.8. Student responsibilities	Class attendance and active participation in lectures, seminars and laboratory exercises, as well as investigative seminars								
2.9. Monitoring student work	Class attendance	YES		Research	YES		Oral exam	YES	
	Experimental work	YES		Report		NO	(other)		
	Essay		NO	Seminar paper	YES		(other)		
	Preliminary exam	YES		Practical work		NO	(other)		
	Project		NO	Written exam	YES		ECTS credits (total)	5	

	Title	Number of copies in the library	Availability via other media
2.10. Required literature (available in the library and/or via other media)	Teaching materials prepared by the course teachers, available through the course website.		www.fkit.unizg.hr
	V. Tomašić, B. Zelić (eds.), Environmental Engineering - Basic Principles, De Gruyter GmbH, Berlin (2018)	2	
	C.D. Cooper, F.C. Alley, Air Pollution Control - A Design Approach, Waveland Press Inc., Long Grove (2002)	2	
	N.P. Cheremisinoff, Handbook of Air Pollution Prevention and Control, Butterworth Heinemann, NY (2002)	1	
2.11. Optional literature	1. L.K. Wang, N.C. Pereira, Y-T. Hung, Air Pollution Control Engineering, Handbook of Environmental Engineering, Vol 1, Humana Press Inc., Totowa (2004) 2. N. de Nevers, Air Pollution Control Engineering, McGraw-Hill, N.Y., (1995) 3. D. Vallero, Fundamentals of Air Pollution, 4th Ed., Academic Press Elsevier Inc., Amsterdam (2008)		
2.12. Other (as the proposer wishes to add)	Best available techniques reference documents (BREFs), Internet and other sources.		