University of Zagreb

1. GENERAL INFORMATION				
1.1. Course teacher	Prof. Nediljka Vukojević Medvidović, PhD Assist. Prof. Ivona Nuić, PhD		1.6. Year of the study	1st year (2nd semester)
1.2. Name of the course	Environmental Remediation Technologies		1.7. ECTS credits	5
1.3. Associate teachers	Prof. Marina Trgo, PhD Assist. Prof. Marin Ugrina, PhD		1.8. Type of instruction (number of hours L + E + S + e-learning)	Total: 60 (L:30,E:0,S:30)
1.4. Study programme (undergraduate, graduate, integrated)	graduate		1.9. Expected enrolment in the course	20
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%)	2

2. COUSE DESCRIPTION	
2.1. Course objectives	Training students for independent and team work in identifying the specific locations of contamination in the environment, and the selection and application of methods of remediation.
2.2. Enrolment requirements and/or entry competences required for the course	
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. • Solve engineering problems using the scientific method combining expert knowledge from chemistry, environmental, and chemical engineering as well as material science and engineering. • Correlate expert knowledge from chemistry, chemical engineering and material engineering with awareness of influence on society, economy and environment. • Plan and independently perform experiments in order to confirm a hypothesis to estimate economic and ecological efficiency of processes. • Demonstrate independence and reliability in independent work, as well as effectiveness, reliability and adaptability in teamwork.
2.4. Expected learning outcomes at the level of the course (3 to 10 learning outcomes)	• Explain complexities of contamination and remediation of contaminated sites • select methods for identification of contaminated sites in the environment • determine the type of contaminants and contamination intensity • predict migration of contaminants in the environment using different models of migration • estimate acceptability of various remediation technologies • select technologies for remediation of soil • select technologies for remediation of sediment • select technologies for remediation of groundwater

2.5. Course content (syllabus)	**WEEK 1.** Importance of remediation of contaminated site in environment. Methods for identification and testing of contaminated sites. **WEEK 2.** Types of pollutants. Qualitative and quantitative identification of contaminant in the contaminated site. **WEEK 3.** Factors influencing migration (spreading) of contaminants in the environment. The role of soil and sediment in retaining and slowing ground water contamination. **WEEK 4.** Models of migration of contaminants in the environment. **WEEK 5.** Environmental remediation techniques: in situ, on site, ex situ. Selection criteria for remediation technologies. **WEEK 6.** Technologies for remediation of soil. Physical remediation: soil encapsulation. Excavation of the soil. Mixing of soil. **WEEK 7.** Chemical soil remediation: electrochemical remediation, flooding, flushing, solidification / stabilization, natural cleaning. **WEEK 8.** Partial exam **WEEK 9.** Thermal soil remediation: incineration, vitrification, solar / photochemical degradation of the soil.Biological soil remediation: bioremediation, bioventilation, phytoremediation, phytoextraction / phytoaccumulation. **WEEK 10.** Remediation of sediment **WEEK 11.** Remediation of groundwater. Ex situ physical / chemical processes: stripping, adsorption, oxidation, separation. **WEEK 12.** Remediation of groundwater. In situ physical / chemical processes: ventilation, stripping, permeable reactive barriers, oxidation. **WEEK 13.** Bioremediation of groundwater. Passive bioremediation. Biostimulation / Bioaugmentation. **WEEK 14.** Phytoremediation. Rhizosphere biodegradation. Fitodegradation. Phytostabilization. Rhizofiltration. Phytovolatilization **WEEK 15.** Partial exam Seminar: Analysis of examples of remediation of contaminated sites. Hydrogeological Parameters Calculation (*hydraulic conductivity, permeability of combination layers, groundwater velocity through different material, Eh-pH diagrams)*. Distribution and retardation coefficient. Remediation of contaminated groundwater by using permeable reactive barriers (PRB). Prediction of migration distribution of harmful substances trough the barrier. Estimation of minimum thickness and longevity of PRB.
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 ☐ (other)
2.7. Comments:	
2.8. Student responsibilities	Attending lectures is 80%, while seminars 100% of the total hours.

2.9. Monitoring student work									
	Class attendance	YES		Research		NO	Oral exam	YES	
	Experimental work		NO	Report		NO	(other)		
	Essay		NO	Seminar paper	YES		(other)		
	Preliminary exam		NO	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)	Yeung A.T., Remediation technologies for contaminated sites, In: Advances in Environmental Geotechnics, Yunmin C., Xiaowu T, Liangtong Z. (Eds.), Proceedings of the International Symposium on Geoenvironmental Engineering in Hangzhou, China, 2010, pp.1-42.	2	
	Dadrasnia A., Shahsavari N.and Emenike C. U., Remediation of Contaminated Sites, Chapter 4, In: Hydrocarbon: V. Kutcherov (ed.), Intech Open, 2013.	2	
	Khan F. I., Husain T., Hejazi R., An overview and analysis of site remediation technologies, Journal of Environmental Management 71 (2004) 95–122.	1	
2.11. Optional literature	Scientific and professional papers		
	L.H. Odell, Treatment technologies for groundwater, American Water Works Association, Denver, 2010.		
	N. L. Nemerow, F.J. Agardy, P. Sullivan, J.A. Salvato, Environmental Engineering, Soil and groundwater treatment and remediation, Sixth Edition, John Wiley & Sons, Inc.New Jersey, 2009.		
	Robert Anderson, Efficient Remediation of Contaminated Sites, A Literature Review , CHALMERS UNIVERSITY OF TECHNOLOGY, Gothenburg, Sweden, 2017 (http://publications.lib.chalmers.se/records/fulltext/254332/local_254332.pdf).		
	Bear J. and Cheng A.H.D, Modeling groundwater flow and contaminant transport, Springer Dordrecht, 2010.		
2.12. Other (as the proposer wishes to add)			