Undergraduate study programme

Course: Introduction to environmental engineering		
Language: English		
Lecturer: Associate prof. Ana Lončarić Božić, PhD Associate prof. Ana Vrsalović Presečki, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory		
Seminar		
		Overall: 30
		ECTS: 4

PURPOSE: Introduction to the study program. Understanding the basic concepts relevant to the study, and the reasons why the environmental engineering was developed in a scientific discipline.

THE CONTENTS OF THE COURSE:

1st week – Biosphere. Technosphere. Ecosystem. Human impact on the environment. The causes and consequences of environmental pollution. Natural resources

2nd week – Methods for solving problems caused by environmental pollution. Environmental management. Basic principles of waste management. The types of waste. Waste disposal. The basic principles of environmental protection. Sustainable Development. The aim of environmental engineering.

3rd week - First preliminary exam

4th week – Courses in the study program of environmental engineering. The role of ecology. The objectives of toxicology. Ecotoxicological research. Toxic effect. Environmental chemistry. The principles of green chemistry.

5th week – The role of organic chemistry in environmental engineering. Microbiology in technological processes for wastewater treatment and disposal. The importance of the mass and energy balances computation in environmental engineering.

6th week – Ecotechnology. The importance of industrial biotechnology in ecotechnology development. The application of industrial biotechnology.

7th week – Second preliminary exam

8th week –Pollution control regarding the type, origin, media and transformation.

9th week – Sources and problems of water pollution by nutrients, organic substances and pathogens.

10^{th} week – Sources and problems of water pollution by toxic organic compounds, heavy metals and suspended solids.

11^{th} week – Third preliminary exam

12^{th} week – Air pollution. Tropospheric and stratospheric ozone. Chapman's ozone cycle. Montreal protocol. Substances that deplete ozone layer.

13^{th} week – Sources and effects of greenhouse gas emissions. Global warming potential. Sources and problems of air pollution by CO_2, SO_2, NO_x, and particulate matter.

14^{th} week – Soil composition and its role in ecosystem functions. Main sources of soil pollution. Mechanisms of transport and transformation of pollutants in soil. Soil remediation methods. Basic principles and tools in preventive approach to environmental protection and management.

15^{th} week - Fourth preliminary exam

GENERAL AND SPECIFIC COMPETENCE:

Acquiring basic knowledge necessary for the successful continuation of the study program.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

Lectures

Course: General and Inorganic Chemistry		
Language: Croatian		
Lecturer: Dr. Svjetlana Krištafor, Assistant Professor; Dr. Ivana Steinberg, Assistant Professor; Dr. Stjepan Milardović, Associate Professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**2**	**30**
		Overall: 90
		ECTS: 8

PURPOSE: To gain a basic knowledge in general chemistry and chemical calculation; to introduce students to the world of chemistry emphasizing the structure of matter; acquiring basic laboratory skills; to introduce students with the properties of chemical elements and compounds based on ionization energy, electron affinity, electronegativity, standard reduction potential, ionic radius etc.; to introduce students with periodic trends, aspects of bioinorganic chemistry, organometallic compounds, as well as theoretical structure models, industrial and analytical aspects of inorganic chemistry; to be able to apply knowledge gained in this course in more advanced courses and throughout ones career.

THE CONTENTS OF THE COURSE:

1st week: Introduction to the course; the importance of chemistry and chemical principles; definitions – chemistry today; atom – an overview of discoveries;

2nd week: The discovery of electron and nucleus; introduction to quantum mechanics; the characteristics of electromagnetic radiation – atomic spectra; quantum theory.

3rd week: Quantum theory and atomic structure; atomic orbitals and energy levels; electronic structure and periodic table.

4th week: Chemical bonds – ionic and covalent bonds; Lewis structures; Resonance.

5th week: Ionic character of covalent bond; intermolecular forces; formal charge; metallic bond; molecular structure and shape; molecular orbital theory; electron configurations and bond order of diatomic molecules

6th week: Valence bond theory and hybridization; geometry of molecule; multiple bonds; coordination compounds.

7th week: The properties of gases; the gas laws; applications of ideal gas law; the kinetic model of gases; real gases; liquids and solids – structure.

8th week: Thermochemistry; enthalpy and entropy; Gibbs free energy;

physical equilibria; phase transitions.

9th week: Chemical equilibria; acids and bases; buffers; solubility equilibria.
10th week: Electrochemistry – oxidation/reduction equations; electrochemical cells; chemical kinetics; reaction rates and mechanisms; nuclear chemistry.

11th week: The law of chemical periodicity and periodic table; periodic trends in physical and chemical properties along the periods and groups; periodicity of chemical properties (electronegativity, ionization energy, electron affinity, oxidation numbers, standard-state reduction potential); periodic trends in physical properties (melting point, boiling points, etc.); the general atomic and physical properties of molecular hydrogen, preparation in industrial and laboratory scale; ionized form of hydrogen (ionic hydrides, covalent hydrides, polymeric and intermediate hydrides); the hydrogen bond and hydrogen isotopes.

12th week: The elements of 18^{th} group (noble gases) - atomic and physical properties of the elements, preparation, production and use; the general chemical properties of the halogen group of elements, physical and chemical trends along the group, the change of electronegativity along the group, properties of compound concerning oxidation numbers in the range :-1, 0, +1, +3, +4, +5, +7; chemical reactivity of diatomic halogens, preparation and properties of hydrogen halides; psudohalogens, preparation and properties; oxoacids and oxoacid salts (preparation and properties).

13th week: The general chemical properties of the chalcogens group of the elements, the properties of compounds concerning oxidation numbers in the range –2, –1, 0, +2, +3, +4, +6; chemical properties and preparation of dioxygen (O_2), ozone (O_3) and atomic oxygen (O); the properties of oxygen compounds concerning negative oxidation state (O^{2-}), (O_2^{2-}), (O_2^{-}), (O3-) and positive oxidation state (O2+); physical properties and structure of water, oxoacids of sulfur, selenium and tellurium, thioacids; redox properties along the group; The general chemical properties of the nitrogen group of the elements;the change of electronegativity along the group, properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +3, +5; preparation and chemical properties of ammonia and ammonium salts, nitric acid, hydrazine, nitrogen oxides (N_2O, NO, NO_2, N_2O_3, N_2O_5) and oxoacid of nitrogen; preparation, use and chemical properties of hydrides of nitrogen, phosphorus, arsenic, antimony and bismuth;

14th week: The general chemical properties of the carbon group of the elements; preparation, physical and chemical properties of carbon (diamond, graphite, fullerene, graphene) CO and CO_2; chemical properties of the carbon (negative oxidation state) compounds (carbides) and silicon (silicide's); chemical properties, preparation and use of silicates and silicon; chemical and physical properties of germanium tin and lead compounds of positive oxidation state (+2, +4); lead battery; the general chemical properties of the boron group of the elements; properties of compounds concerning oxidation states in the range –3, -1, 0, +1, +2, +3; preparation, use and chemical properties of ortoboric acid; preparation, use and chemical properties of aluminum, aluminum trihalides, amphoteric properties of aluminum and aluminum passivity; chemical properties of indium and gallium compounds.

15th week: The 2nd group of the elements (alkaline earth metals); chemical reactivity and trends of chemical and physical properties along the group; introduction to hydrides, oxides, oxoacides, hydroxides and organometallic compounds; the 1st group of the elements (alkali metals); chemical reactivity and trends of chemical and physical properties along the group; introduction to hydrides, peroxides, superoxide's, hydroxides and organometallic compounds; preparation of NaOH, NaHCO3, NaCl and gypsum.

GENERAL AND SPECIFIC COMPETENCE:

The main objective of this course is to give students a basic foundation in chemistry, including development of skills required for problem solving and the application of basic chemical concepts. Students will learn to think at the atomic structural level of matter and to relate the electronic structure of atoms to the chemical properties of elements. The understanding of how atoms combine with one another and its importance in relation to the research in pharmaceuticals, agricultural chemicals, polymers and synthetic materials. After completion of this course, students will be able to use the periodic table and understand the symbolism and language of chemistry. After the successful completion of the laboratory part of this course, students will have acquired the skills necessary for scientific work – critical thinking and observation skills, ability to safely handle chemical reagents. The students will understand the basic of inorganic chemistry and adequate application of low of periodicity to predict the properties of elements or compounds. Using the modern theory of bonding students will be able to predict the structure, reactivity, acid-base properties and redox properties of elements and compounds. After the successful completion of laboratory part of this course student acquire skills necessary for scientific work – thinking and observation skills, ability to safely handle chemical reagents.

KNOWLEDGE TESTING AND EVALUATION:

Three written tests during the semester

Written and oral examinations

Exam related to the laboratory practice (successful completion of laboratory practice is needed for completion of the course)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. I. Filipović, S. Lipanović: "*Opća i anorganska kemija*", Školska knjiga, Zagreb, 1991.

2. N. N. Greenwood, A. Earnshaw: "*Chemistry of the Elements*", Pergamon Press, Oxford, 2002.

3. D. F. Shriver, P. W. Atkins: "*Inorganic Chemistry*", 3rd ed. Oxford University Press, 1999.

4. P. Atkins, L. Jones: "*Chemical Principles: The Quest for Insight*", 4th ed. New York, NY: W.H. Freeman and Company, 2007.

Course: Microbiology		
Language: English		
Lecturer: **Assoc. Prof. Marija Vuković Domanovac, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	
		Overall:60
		ECTS: 6,0

PURPOSE:

Introduction to the fundamentals of microbiology. The study of structure, physiology, reproduction and growth of bacteria, fungi, algae and protozoa. Macromolecules, enzymes, metabolic activity of microorganisms and biotechnological processes.

THE CONTENTS OF THE COURSE:

1st week: Introduction, history of microbiology

2nd week: The molecules of living systems

3rd week: The study of microbial structure: microscopy and specimen preparation

4th week: The structure and function of prokaryotic and eukaryotic cells

5th week: 1st partial test

6th week: Structure and classification of enzymes, mechanisms of enzymatic reactions, effect of environmental conditions on enzyme activity

7th week: Energy metabolism

8th week: Central pathways for the production of energy

9th week: Biochemical pathways and mechanisms of selected fermentation and anabolism

10th week: 2nd partial test

11th week: Determination of metabolic activity and metabolic differences between microorganisms

12th week: Microbial growth

13th week: Isolation and identification of the main groups microorganisms from environment

14th week: Control of microorganisms growth

15th week: 3nd partial test

GENERAL AND SPECIFIC COMPETENCE:

Students acquire the ability to identify the major groups of microorganisms, understand their physiological needs and biochemical capabilities. This fundamental knowledge will help master the parts of the course during the study where biological processes will be interpreted.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3) or exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. S. Duraković, Opća mikrobiologija, Prehrambeno tehnološki inženjering, Zagreb, 1996.
2. L.M. Prescott, J.P. Harley, D.A. Klein, Microbiology, 3rd Edition, Wm.C. Brown Publishers, Boston, 1996.
3. J.N. Lester, J.W. Birkett, Microbiology and Chemistry for Environmental Scientists and Engineers, E&FN SPON, London, 1999.
4. J. Nicklin, K. Graeme-Cook, R. Killington, Microbiology, 2nd Edition, BIOS Scientific Publishers Limited, Oxford, 2002.

Course: Organic chemistry		
Language: English		
Lecturer: Dr. Tatjana Gazivoda Kraljević, assis. prof.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar	**0**	**0**
		Overall: 60
		ECTS: 5

PURPOSE:
The objective of the course is to give students the knowledge required to understand the basic principles of modern organic chemistry and how to use the fundamental knowledge of organic chemistry in industry.

THE CONTENTS OF THE COURSE:

1st week: Introduction to carbon compounds and chemical bonds; classes of carbon compounds, functional groups. Introduction to organic reaction: acids and bases; classification and nomenclature of organic compounds

2nd week: Classes of carbon compounds: functional groups, hydrocarbons: reperesentative alkanes, alkenes, alkynes, aromatic compounds, carboxylic acid derivatives, nomenclature

3rd week: Alkanes and cycloalkanes: nomenclature, conformational analysis, introduction to synthesis

4th week: Alkenes and alkynes: properties and synthesis, elimination and addition reactions , stereochemistry.

5th week:: Stereochemistry: structural isomers and stereoisomers, optical activity, enantiomers and chiral molecules, diastereoisomers, realtive and absolute configurations, the biological importance of chirality.

6th week: Alkyl halides: ionic reaction: **n**ucleophilic substitution (SN1 i SN2) and elimination reactions (E1 and E2), stereochemistry of reactions

7th week: Alcohols and ethers: structure and nomenclature, synthesis and reactions, organometallic compounds

8th week: Aldehyde and ketones: nomenclature, synthesis, nucleophilic addition to the carbonyl group, reduction reactions, reactions of alpha-hydrogen

9th week: Aromatic compounds: aromaticity, properties, the Kekulé structure of benzene, nomenclature of benzene derivatives, reactions of electrophilic aromatic substitutions, inductive and resonance effects,

10th week: Aromatic compounds: Mechanism of electrophilic aromatic substitution and reactions of substituted benzenes: activating and directing effects

11th week: Carboxylic acids and their derivatives (esters, anhydrides, amides): nomenclature, synthesis and reactions, nucleophilic addition-elimination reaction at the acyl carbon

12th week: Amines: nomenclature and structure of amines, basicity of amines, synthesis of amines.

13th week: Hydrocarbons: nomenclature, structure, properties and reactions. Radical reactions; polimers

14th week: Introduction to structure determination of organic compounds: infrared spectroscopy (IR), nuclear magnetic resonance (NMR) and mass spectrometry (MS)

15th week: "Green chemistry" - principles and application of green reactions in organic chemistry and industry

GENERAL AND SPECIFIC COMPETENCE:

Qualifying students to connect and use the terms of organic chemistry, to understand, analyse and apply the chemical transformations and mechanisms for alkanes, alkenes, alkynes, alkyl halides, alcohols, aromatic and carbonyl compounds

KNOWLEDGE TESTING AND EVALUATION:

Exams related to laboratory practices.
3 partial written tests during the semester (60% of points on each of the exams brings the release of the oral examination).
Written exam (50% of the points needed for passage).
Oral examination.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionary.

LITERATURE:

1. T.W.G. Solomons, "Organic Chemistry", Eight edition, John Wiley & Sons, New York, USA, 2004.
2. K.P.C. Vollhardt, N.E. Schore, "Organic Chemistry: Structure and Function", Fifth edition, W.H. Freeman and Company, New York, USA, 2007.
3. L.G. Wade, "Organic Chemisty", Sixth edition, Pearson Education, Inc., New Jersey, USA, 2006.
4. J. Clayden, N. Greeves, S. Warren, P. Wothers, "Organic Chemistry", Oxford University Press, New York, USA, 2001.
5. S. H. Pine, Organska kemija (prijevod I. Bregovec, V. Rapić), Školska knjiga, Zagreb, 1994.
6. H. Vančik, Temelji organske kemije, TIVA, Varaždin, 2012.
7. V. Tralić-Kulenović, B. Karaman, L. Fišer-Jakić, Uvod u organsku kemiju, Tekstilno-tehnološki fakultet, Zagreb, 2004.

Course: Physical Chemistry		
Language:		
Lecturer: Krešimir Košutić		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**2**	**30**
Seminar	**1**	**15**
		Overall: 90
		ECTS: 7

PURPOSE:

Understanding of basic laws and theories of physical chemistry as applied in practice of chemical engineering. The course is not only a collection of facts but an introduction to ways of thinking about the world. Development of capabilities of logical problem solving and equation derivation.

THE CONTENTS OF THE COURSE:

1. week: Introduction, properties of gasses, states and laws of ideal and real gasses
2. week: Thermodynamics: heat and work, The first law, internal energy, enthalpy, heat capacities; Thermochemistry: Hess's law, Kirchhoff's law
3. week: Spontaneous processes and equilibrium, Carnot cycle, The second law of thermodynamics, reversibility of processes, Entropy, Gibbs free energy,
4. week: The third law of thermodynamics, dependence of Gibbs energy on temperature and pressure, mixtures, chemical potential, Gibbs-Duhem equation
5. week: Phase equilibria, Clapeyron and Clausius-Clapeyron equation, triple point, phase rule
6. week: Raoult's law, colligative properties of mixtures, Henry's law, distillation, vapour pressure diagrams, boiling diagrams, distribution law, crystallization, osmotic equilibrium

First partial exam

7. week: Description of chemical equilibrium , thermodynamic equilibrium constant, Response of equilibrium to temperature (van't Hoff equation) and pressure
8. week: Surface phenomena: surface tension, surface films, adsorption (adsorption isotherms)
9. week: Conductivities of electrolyte solutions, weak and strong electrolytes (Ostwald's dilution law, Debye-Huckel theory and law)
10. week: Equilibrium electrochemistry, half- reaction and electrodes, electrode potential, Galvanic cells, electromotive force, Nernst equation
11. week: Physical processes, (diffusion, Fick laws), rates of chemical reaction-

definition, rate laws and rate constants, reaction order, and determination of rate law
12. week: Kinetics of complex reaction (reverse,-parallel, and consecutive reactions)
13. week: Kinetics of complex reations-chain reaction, Temperature dependence of reaction rates
14. week: The chemistry of stratospheric ozone-ozone decomposition
15. week: Catalysis and catalyst-homogeneous and heterogeneous catalysis; Second partial exam

Laboratory work:
1. Cryoscopy
2. Nernst distribution law
3. Boiling diagram
4. Adsorption-Freundlich isotherm
5. Electromotive force of galvanic cell
6. Conductivity of electrolyte solutions
7. Determination of constant rate and reaction order of chemical reaction (decomposition of H_2O_2)

GENERAL AND SPECIFIC COMPETENCE:

Describing the basic physical chemistry laws regarding gasses, thermodynamics, phase equilibria, chemical equilibria, surface phenomena (surface tension and adsorption), equilibria in electrolyte solution, and chemical kinetics.
Applying knowledge of mathematics and deriving the equations (clearly describing the physical phenomena under consideration).
Preparing and performing laboratory experiments.
Analysis and interpretation of experimental results.
Preparation of laboratory reports.

KNOWLEDGE TESTING AND EVALUATION:

Entrance and final colloquium in laboratory work, partial exams, oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student opinion surveys

LITERATURE:

P. Atkins, J. de Paula, Atkin's Physical Chemistry, 8th edition, Oxford University Press, Oxford 2006.

Course: Environmental protection - Undergraduate study Environmental Engineering		
Language: English		
Lecturer: Felicita Briški		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5

PURPOSE: Introduction to the structure and basic processes that occur in the atmosphere, lithosphere and hydrosphere. Understanding the effect of different sources of pollution in the abiotic and biotic (living creatures in the environment) resources and human health, the treatment process and preventing the formation of waste streams (waste water, solid waste, toxic gases), and learning about legislation to protect the environment.

THE CONTENTS OF THE COURSE:

Lecture:

Week 1: The importance of environmental protection and the application of chemical engineering methodologies to protect the ecosystem, population, demographic period, natural resources

Week 2: The ecosystem and physical environment, ecosystem and energy circulation of substances in the environment

Week 3: Historical Overview of pollution and environmental damage, environmental law Croatia

Week 4: Classification of the aquatic environment and water sampling for analysis, drinking water supply, pollution of drinking water sources and treatment

Week 5: Classification, composition, analysis, and wastewater disposal, the impact of untreated wastewater to the receivers

Week 6: Processes and stages of wastewater treatment, the choice of process equipment

Week 7: first partial exam

Week 8: The formation of soil (physical, chemical and biological processes) land use, problems of excessive use of pesticides

Week 9: Solid waste products division according to the origin, waste incineration, sanitary landfill, composting waste

10th week: The composition of the atmosphere, the origin and spread of pollution, air quality measurement

11th week: Damage to the ozone layer, climate change,

Week 12: Sources of noise, a division of sound, noise measurement, volume level and noise protection, electricity, illumination, light pollution and measures to reduce light pollution

13th week: Thermal contaminated types of pollution when operating thermal and nuclear power plants, the impact of untreated wastewater flows receivers, disposal procedures for thermal pollution, the impact of energy on the environment and energy strategy

Week 14: The ionizing radiation, radiation sources and radioactive waste, nuclear energy production, radioactive waste management of nuclear power plants

Week 15: 2nd partial exam
Laboratory exercises and field work: (a block of 3 hours):
Week 1: The impact of harmful compounds on the microbial community in the soil, composting of biodegradable solid waste
Week 2: Analysis of the distribution of harmful gases in indoor and outdoor
Week 3: Sampling and bacteriological quality assessment of natural and waste water
Week 4: Sampling and physico-chemical quality assessment of natural and waste water
Week 5: Field work (device for wastewater treatment and / or composting)
Seminars:
Case study "Case studies" in the field of water, air and soil.

GENERAL AND SPECIFIC COMPETENCE: Upon completion of the course the student will understand the extraordinary complexity and precision with which natural ecosystems function. They will acquire a basic knowledge of chemical engineering design and analysis of the impact of pollution on the environment and how to remove the contamination and prevent further accumulation in the environment for a sustainable development of our planet.

KNOWLEDGE TESTING AND EVALUATION: Two partial exams (after certain units of material) that are recognized as passed exam if both positively evaluated and written and oral exams within specified examination periods.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. J.A. Salvato, et al: Environmental Engineering, 2003, John Wiley&Sons, Hoboken, New Jersey
2. P.A. Carson, C.J. Mumford: Hazardous Chemicals Handbook, 2002, Butterworth-Heinemann, Oxford
3. M.L. Shuler, F. Kargi: Bioprocess Engineering, 2002, Prentice hall PTR Upper Sadle River
4. T.J. Casey: Unit Treatment Processes in Water and Wastewater Engineering, 1996, John Wiley&Sons,
5. R.L. Crawford, D.L. Crawford, Bioremediation: Principles and Applications, 1996, Cambridge University Press, Cambridge

Course: Fluid mechanics (EI)		
Language: English		
Lecturer: Jasna Prlić Kardum, Gordana Matijašić		
TEACHING	*WEEKLY*	*SEMESTER*
Lectures	3	45
Laboratory	1	15
Seminar	1	15
		Overall: 75
		ECTS: 6

PURPOSE: Acquiring knowledge of the mechanical behaviour of fluids. Description of macroscopic phenomena due to practical applications in chemical process and related industries.

THE CONTENTS OF THE COURSE:

Week 1
Forces in the fluid. Rheological characterization and fluid classification. Newtonian fluids. Newton's law of viscosity.

Week 2
Non-newtonian fluids. Mathematical description of rheological behaviour. Time dependent rheological behaviour. Rheological diagram. Calculation examples.

Week 3
Fluid statics. Euler equations. Dynamics of incompressible fluids. Conservation laws. Calculation examples.

Week 4
Flow equations. Navier-Stokes equation. NSE solution for viscous, incompressible fluids. Calculation examples.

Week 5
Elementary fluid dynamics of non-newtonian fluids. Flow of pseudoplastic and Bigham fluids in horizontal pipes; velocity distribution; pressure drop; definition of Reynolds number and friction factor. Calculation examples.

Week 6
Partial exam I

Week 7
Flow through narrow orifices; cavitation; flow from tank with maintained constant and variable fluid level. Calculation examples.

Week 8
Classification of pumps; scheme, characteristics, selection criteria and pump design. Calculation examples.

Week 9
Complex pipelines; fundamental energy principles for transport through branched pipeline, resistance coefficient of pipe fittings, evaluation of flow rate and pressure drop. Calculation examples.

Week 10
Partial exam II

Week 11
Compressible flow; definition of ideal gas. Conservation laws. Isothermal flow of an ideal gas in horizontal pipe; evaluation of pressure drop. Calculation examples.

Week 12
Two-phase flow (gas-liquid). Fundamentals, flow types in horizontal pipe, methods for prediction of flow type, evaluation of pressure drop. Calculation examples.

Week 13
Flow of heterogeneous systems (liquid-solid; gas-solid). Heterogeneous suspensions, hydraulic transport, evaluation of pressure drop. Homogeneous suspensions; factors effecting rheological behaviour. Pneumatic transport, evaluation of pressure drop. Calculation examples.

Week 14

Steady flow in open channel; types of flow, uniform and non-uniform flow, the phenomenon of hydraulic jump. Flow through granular layer; hydrodynamic laws. Calculation examples.

Week 15
Partial exam III

GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge of the principles of fluid behaviour necessary to understand fundamental chemical engineering courses.

KNOWLEDGE TESTING AND EVALUATION: 3 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student survey.

LITERATURE:

B. S. Masey, Mechanics of Fluids, 2nd Ed., Butler&Tanner, London, 1976.

D. N. Roy, Applied Fluid Mechanics, J. Wiley, New York, 1989.

J. Ferguson, Z. Kemblowski, Applied Fluid Rheology, Elsevier, London

I. H. Shames, Mechanics of Fluids, 4tf Ed., Mc Graw-Hill Companies, New York, 2003.

M. Pečornik, Tehnička mehanika fluida, Školska knjiga, Zagreb, 1985.

I. P. Granet, Fluid Mechanics for Engineering Tehnology, Simon&Schuster, New York, 1989.

B. R. Munson, D. F. Young, T. K. Okiishi, Fundamentals of Fluid Mechanics, 5th Ed.,J. Wiley&Sons. Ltd., 2005

V. Jović, Osnove hidromehanike, Element, Zagreb 2006. (Udžbenici Sveučilišta u Splitu)

Course: ENVIRONMENTAL CHEMISTRY		
Language: Croatian		
Lecturer: Dr. sc. Stjepan Milardovic, associate professor, dr. sc. Dragana Mutavdžić Pavlović, associate professor, dr. sc.Tatjana Gazivoda Kraljević, assistant professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**3**	**45**
Seminar	**0**	**0**
		Overall: 90
		ECTS: 7

PURPOSE:

Introducing students with chemical equilibrium and possible interaction between natural components (compounds) and environmental pollutants presented in water soil and air. Multidisciplinary approach to control of environmental quality.

THE CONTENTS OF THE COURSE:

1. Introduction to environmental chemistry. Preparation of complex between natural presented ligands and metals (complexation and chelation), preparation of organometallic compounds, types of ligands presented in environment, stability of metal natural ligands compounds, stability of coordination compounds, coordination bond, stability of complex compounds.

2. Solubility of complex compounds (NTA, EDTA, polyphosphate, amino acid), hydrolysis, cationic acids.

3. Determination of redox processes and equilibrium in water, Purbeix diagram, Latimer's diagram, Frost's diagram, pε-pH diagram.

4. Ion-selective electrode application for potentiometric determination of alkali cations in water.

5. The interaction of the environment components; The cycle of basic processes in the biosphere; The water cycle; The carbon cycle; The nitrogen cycle; Organic pollutants in soil; Organic pollutants in water; Pesticides.

6. Atmospheric chemistry. Organic pollutants in air; photochemical processes in atmosphere; Photodegradation of organic pollutants; Photochemical smog and a threat to the global atmosphere; Damage to the ozone layer.

7. Environmental biochemistry; The biochemical mechanisms of toxicity; Toxicology of organic compounds; Introduction to ecotoxicology.

8. "Green" chemistry in the application of basic organic reactions: Nitration; Halogenation; Alkylation; Oxidation; Sulphonation

9. Modern organic synthesis - a "green" approach: Reactions without solvent;

Micowave reactions; Tandem and domino reactions; Application of "green" solvents.

10. Access to environmental analysis. Classical chemical analysis. Instrumental analytical methods. *In situ* process analysis. Trace contaminants analysis. Data evaluation and interpretation. Information for users.

11. Water pollution by heavy metals and other inorganic compounds. Water pollution by organic compounds. Reactions of organic compounds with metals in water. The most common organic pollutants in water. Sampling, separation and analysis of contaminants in water.

12. Suspended colloidal particles in water. Sediment. Equilibria at the interface. Trace metals and organic compounds in sediment and suspended particles.

13. Composition of the atmosphere. Gases. Acid-base reactions in the atmosphere. Acid rain. The reactions of atmospheric ozone. Primary and secondary pollutants of the atmosphere. Inorganic contaminants. Suspended particles.

14. Sampling and the methods for detection and the determination of pollutants in the atmosphere.

15. Soil. Mineral and organic components of soil. Soil contamination by organic and inorganic pollutants. The mechanisms of binding and mobility of contaminants in the soil. Analysis of soil. Methods for monitoring the mobility of contaminants in the soil. Information about the environmental quality on the basis of chemical analysis.

Laboratory practice

1. Determination of chloride in soil suspension by chloride ion-selective electrode.
2. Determination of potassium concentration after soil extraction by ion-selective electrode
3. Determination of calcium after soil extraction by calcium ion-selective electrode, determination of calcium and magnesium concentration by titrimetric method.
4. Determination of ammonium in soil extraction by ion-selective electrode, and estimate of cations exchange capacity.
5. "Green" chemistry in the application of basic organic reactions: a) Electrophilic aromatic substitution: nitration of salicylic acid and bromination acetanilide; b) Acetylation of primary amines: synthesis of acetanilide; c) Aldol condensation: synthesis of dibenzalpropanone
6. Modern organic reactions - a "green" approach: microwave assisted [4+2] cycloaddition: Diels-Alder reaction of furane and maleic acid; Domino reaction: synthesis of dihydropyrimidinone
7. “Green” solvents: synthesis and application of ionic solvents 1-pentyl-3-methylimidazole bromide, [pmIm]Br
8. Paper recycling
9. Analysis of water: sampling, determination of temperature, determination of evaporation residue, determination of specific conductivity, determination of pH, determination of water hardness: total, calcium, magnesium and carbonate hardness, alkalinity determination, determination of sulphate and nitrate in water.
10. Soil analysis: determination of soil acidity and determination of humus in the

soil.

GENERAL AND SPECIFIC COMPETENCE:

Introduction to chemistry of different environmental pollutants, introduction to pollutants identification and analytical determination

KNOWLEDGE TESTING AND EVALUATION:

Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Continuous evaluation.

LITERATURE:

1. D.A. Skoog, D.M. West, F.J. Holler, OSNOVE ANALITIČKE KEMIJE, Školska knjiga Zagreb, 1999.

2. J. Martinović, TLOZNANSTVO U ZAŠTITI OKOLIŠA, Pokret prijatelja prirode Lijepa naša, Zagreb 1997.

3. S.E. Manahan, ENVIRONMENTAL CHEMISTRY, 8. ed., CRC Press, 2005.

4. L.C. Eubanks et all., CHEMISTRY IN CONTEXT-Applying Chemistry to Society, Fifth Ed., Mc Graw Hill, Boston, 2006.

5. K.M. Doxsee, J. E. Hutchinson, GREEN ORGANIC CHEMISTRY, Thomson-Brooks/Cole, United Kingdom, 2004

6. The group of authors, ANALITIKA OKOLIŠA (ur. M. Kaštelan-Macan, M. Petrović), HINUS i FKIT, Zagreb 2013.

Course: Mass ana energy balance		
Language: English		
Lecturer: Associate prof. Ana Vrsalović Presečki, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory		
Seminar	**3**	**45**
		Overall: 75
		ECTS: 6

PURPOSE: Introduce students to the application of the law of conservation of mass and energy in chemical processes; teach them the basics of chemical engineering process analysis and computation mass and energy balances of steady-state and unsteady-state processes.

THE CONTENTS OF THE COURSE:

1st week

The fundamental laws, concepts and techniques in chemical engineering analysis. Processes and process variables. Mass balances (general equation, differential and integral balance).

2nd week

Mass balance of the steady-state processes. Mass balances of the unsteady-state processes. Computation based on balances of steady-state processes (systems of linear equations).

3rd week

Mass balance of the physical process in a single process unit.

4th week

Mass balance of the process with chemical reaction in a single process unit.

5th week

Mass balance of combustion process

6th week

Mass balance of physical processes performed in the multiple unit processes.

7th week

Mass balance of process with chemical reaction performed in the multiple unit processes.

8th week

Mass balance of physical and chemical processes with recycle, bypass flow and partial purge.

9th week

Energy and chemical engineering. Fundamental concepts in energy balance. The general equation of the energy balance.

10th week

Energy balance of the closed system. Energy balance of open systems (steady state process).

11th week

Computation in chemical engineering based on energy balance. Energy balance of single component process. Energy balance of multi-component process.

12th week

Energy balance of the physical process.

13th week

Energy balance of the process with a chemical reaction.

14th week

Energy balance of the combusting process.

15th week

Simultaneous mass and energy balances. Computation based on the energy balances with the use of numerical methods.

GENERAL AND SPECIFIC COMPETENCE:

Acquiring basic knowledge of chemical engineering methodology needed to solve practical problems in the process analysis.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. Himmelblau, D. M.: Basic Principles and Calculations in Chemical Engineering, Prentice Hall, New Jersey, 1982.
2. Felder, R. M., Rousseau, R. W.: Elementary Principles of Chemical Processes, J. Wiley, New York, 1986.
3. Luyben, W. L., Wenzel, L. A.: Chemical Process Analysis: Mass and Energy Balances, Prentice Hall, New Jersey, 1988.

Course: Modern analytical techniques in environmental analysis		
Language: English		
Lecturer: prof. dr. sc. Sandra Babić, prof. dr. sc. Sanja Papić, prof. dr. sc. Tomislav Bolanča		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar		
		Overall: 45
		ECTS: 5

PURPOSE:

The main purpose is to provide knowledge about steps in analytical procedure (sampling, separation, measurements and evaluation of results), modern analytical methods and their application in analyses of complex environmental samples.

THE CONTENTS OF THE COURSE:

1. Analytical system. Sampling from the environment.
2. Sample preparation.
3. Modern methods of analyte isolation: solid-phase extraction, microwave assisted solvent extraction, ultrasound assisted extraction.
4. Overview of methodologies for identification and quantification of organic and inorganic pollutants from environment (soil, water, sediment).
5. Introduction to spectroscopy. Molecular spectroscopy.
6. Atomic absorption spectroscopy, mass spectrometry.
7. Chromatography: gas, ion and thin layer chromatography.
8. High performance liquid chromatography. Hyphenated techniques.
9. Analytical method validation. Comparison of analytical methodology. Selection of adequate methodology.
10. Statistical data treatment and extraction of useful environmental information.
11. Industrial wastewaters. Types of pollutants. Parameters of industrial wastewater characterization. Indicators of water quality.
12. Importance, application and fundamentals of modern analytical method for the determination of the content of total organic carbon (TOC)
13. Fundamentals of the modern colorimetric method for the determination

of chemical oxygen demand (COD)

14. Importance, application and fundamentals of modern analytical method for the determination of the content of organic halogenides; adsorbable organic halogenides (AOX)

15. Modern methods for the toxicity determination.

GENERAL AND SPECIFIC COMPETENCE:

Development of basic knowledge on principles and application of modern analytical techniques in environmental analysis.

KNOWLEDGE TESTING AND EVALUATION:

3 midterm exams

writing exam

oral exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. D. A. Skoog, D. M. West, F. J. Holler, Osnove analitičke kemije, Školska knjiga, Zagreb, 1999.
2. D. C. Harris: Quantitative Chemical Analysis, W. H. Freedman and Co., New York, 2001.
3. M. Csuros: Environmental Sampling and Analysis, Lewis Publishers, New York 1997.
4. F.W. Fiefield, P.J. Haines, Environmental Analitical Chemistry, Blackie Academic and Professional, London, 1995

Course: Unit operations in environmental engineering		
Language: English		
Lecturer: Aleksandra Sander, Gordana Matijašić		
TEACHING	*WEEKLY*	*SEMESTER*
Lectures	3	45
Laboratory	1	15
Seminar	1	15
		Overall: 75
		ECTS: 7

PURPOSE: Introducing students to the methods of characterization of disperse systems, processing path of the material transformed in mechanical operations, parameter influence on the response of individual separation process.

Provide students with knowledge that allows them to evaluate and select the optimal thermal separation process, general procedure of equipment design, with reference to energy savings and environmental impact.

THE CONTENTS OF THE COURSE:

Week 1
Introduction to unit operations. Mechanical and thermal separation processes.

Week 2
Basics of processes with particulate systems from macroscopic scale. Characterization of dispersed systems. Calculation examples.

Week 3
Basics of mechanical separation. Gravitational sedimentation. Equipment selection. Calculation examples.

Week 4
Centrifugal sedimentation. Theoretical background and equipment selection, calculation examples.

Week 5
Filtration and centrifugal filtration. Theoretical background and equipment selection, calculation examples.

Partial exam I: Characterization of dispersed systems, sedimentation.

Week 6
Fluid and suspension mixing. Impeller types. Design of mixing systems. Basics of powder mixing. Theoretical background, equipment, equipment selection, calculation examples.

Lab assignment I: Filtration test.

Week 7
Comminution. Theoretical background, equipment, equipment selection, calculation examples.

Week 8
Lab assignment II: Comminution kinetics.

Partial exam II: Filtration, mixing and comminution.

Week 9
Basics of thermal separation processes.

Week 10
Heat exchangers. Evaporation. Methods of energy savings in evaporation. Equipment classification and selection. Calculation examples.

Week 11
Crystallization. Kinetics, nucleation and growth mechanisms. Equipment classification. Calculation examples.

Lab assignment III: Floating head heat exchanger.

Week 12
Drying. Kinetics and mathematical description of the process. Energy savings. Equipment classification. Calculation examples.

Week 13
Partial exam III: Heat exchangers, evaporation, crystallization, drying.

Distillation. Implementation methods. Column design (height, diameter, number of theoretical units). Calculation examples.

Week 14
Absorption. Column absorption. Equipment classification. Calculation examples.

Lab assignment IV: Rectification.

Week 15
Extraction. Methods of process implementation. Equipment classification. Calculation examples.

Partial exam IV: Distillation, absorption, extraction.

GENERAL AND SPECIFIC COMPETENCE: Acquiring knowledge necessary for equipment selection, definition of optimal process conditions and analysis of complex processes in chemical engineering.

KNOWLEDGE TESTING AND EVALUATION: 4 partial exams. Students who do not achieve minimum points through partial exams have to complete the written and oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS: Student survey.

LITERATURE:

M. Hraste, Mehaničko procesno inženjerstvo, Hinus, Zagreb 2003.

M. Rhodes, Introduction to Particle Technology, John Wiley, London 1998.

A. Rushton, A.S. Ward, R.G. Hodlich: Solid –Liquid Filtration and Separation Technology, VCH Weinheim 1996.

K.Satler, H.J.Feindt, Thermal Separation Processes – Principles and Design, VCH Verlagsgesellschaft mbH, Weinheim; 1995.

J.D.Seader, E.J. Henley, Separation Process Principles, John Wiley & Sons, Inc., 2006.

Course: Environmental management systems		
Language: English		
Lecturer: Associate prof. Ana Lončarić Božić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE: Introduction to the aims, methodology and structure of Environmental Management Systems (EMS). Overview of knowledge and skills for development and implementation if EMS as one of sustainable development tools.

THE CONTENTS OF THE COURSE:

1st week – Preventive approach in environmental protection and management. Basic principles and elements of sustainable development. Introduction to EMS based on Deming's cycle.

2nd week – Basic terms and definitions. Overview of ISO 14001 (HR EN ISO 14001:2009) standard. Purpose of standardisation. Positive features of EMS implementation.

3rd week –Basic roles and focus of EMS. Structure and main elements of EMS. Concept of continual improvement.

4th week – Requirements of ISO 140001 for EMS. Environmental policy. Objectives and targets. Examples of setting "smart" objectives.

5th week –Elements of planning process. Environmental aspects and impacts. Identification of legal requirements and significant aspects. Case studies.

6th week – Significance of defined roles, resources and responsibilities for successful implementation of EMS. Competences and communication.

7th week –Types and management of EMS documentation. Differences between documents and records. Case studies.

8th week –1st partial exam

9th week – Emergency preparedness and response. Analysis of processes and activities, aspects and potential impacts; case study.

10th week – Assessment of compliance of EMS with ISO 14001 standard. Identification of non-conformances and appropriate corrective and preventive actions. EMS audit and management review. Identification of significant aspects

and impacts: service industry case study.

11th week – Basic elements and methodology of Life cycle assessment (LCA) methodology. LCA as sustainable development tool.

12th week – Cleaner production. Correlation of EMS with waste management strategy within Cleaner production. Identification of waste sources and corresponding preventive measures of Cleaner production. Cleaner production methodology; case study.

13th week – Differences and similarities of environmental management systems according to EMAS and ISO 14001.

14th week – Occupational health and safety; OHSAS18001. Integrated management systems.

15th week – Programme Responsible care. Principles and guidelines. Correlation of Responsible care elements with environmental management system.

GENERAL AND SPECIFIC COMPETENCE:

Adoption of proactive approach in environmental protection and management. Understanding the opportunities of continual improvement of environmental performances by adoption and implementation of EMS.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1) Sheldon, C.: ISO 14000 and Beyond, Environmental management systems in real world, Greenleaf Publishing, UK,1997.
2) Lectures

Course: Air, Water and Soil Management		
Language: English		
Lecturer: **Assoc. Prof. Marija Vuković Domanovac, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 4,0

PURPOSE: Introduction to the negative processes that affect all the resources in the environment - air, water and soil. Sustainable environment - protection of resources and pollution prevention. Legislation.

THE CONTENTS OF THE COURSE:

1st week: Sources of air pollution

2nd week: Sampling of particles, gases and flue gases indoors and outdoors

3rd week: Measuring Air Pollution. Data analysis

4th week: Sources, measurements and methods of noise pollution reduction

5th week: 1st partial test

6th week: Water resources - management and protection

7th week: Drinking water preparation

8th week: Wastewater treatment and sludge disposal

9th week: Industrial wastewater

10th week: 2nd partial test

11th week: Soil formation, soil fertility and soil erosion

12th week: Soil production, physiological and ecological functions

13th week: Land use

14th week: Soil and groundwater remediation

15th week: 3nd partial test

GENERAL AND SPECIFIC COMPETENCE: Understanding the importance of the environmental elements. Students will acquire basic knowledge about eco engineering planning and the impact analysis of pollution on the environment and how to remove the contamination and prevent damage to the environment for sustainable development.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (3) or exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

5. A. Wellburn, Air Pollution and Climate Change, Longman Scientific & Technical with John Willey & Sons, New York, 1994.
6. 2. E.A. Fitzpatrick, An Introduction to Soil Science, Longman Scientific & Technical, Essex, 1995.
7. 3. T.J.Casey, Unit Treatment Processes in Water and Wastewater Engineering, John Wiley & Sons, New York, 1997.
8. 4. J.A. Salvato, et al: Environmental Engineering, John Wiley&Sons, Hoboken, New Jersey, 2003.

Course: Waste Management		
Language: English		
Lecturer: Dr. Hrvoje Kušić, assistant professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 30 + 0 + 30
		ECTS: 4

PURPOSE:

Introducing the waste management issues, the ways of waste formation, types of waste and possibilities for waste reduction, assessment and evaluation, treatment and disposal

THE CONTENTS OF THE COURSE:

1. **week:** Introduction to waste management. Waste; basic principles.
2. **week:** Classification of waste according to the way of its formation and characteristics.
3. **week:** National legal requirements for the field of waste management. National Strategy and Action plan for waste management.
4. **week:** Sustainable development and waste management. Cleaner production; basic principles.
5. **week:** 1st partial exam.
6. **week:** Waste management hierarchy, prevention strategies.
7. **week:** Waste in chemical industry; waste formation inducement, possibilities for waste reduction.
8. **week:** Municipal and industrial waste. Inert and non-hazardous waste.
9. **week:** Hazardous waste. Special categories for waste classification
10. **week:** 2nd partial exam.
11. **week:** Measures for waste management. Waste collection, sorting, recycling
12. **week:** Waste disposal and Landfills.
13. **week:** Landfill leachate; basic principles and treatment
14. **week:** Waste treatment methods
15. **week:** 3rd partial exam

GENERAL AND SPECIFIC COMPETENCE:

Understanding of waste related environmental issues and acquiring of basic principles of waste management and measures for management of different waste types

KNOWLEDGE TESTING AND EVALUATION:

1. Partial exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

A. B. Crittenden, S.Kolaczkowski, Waste Minimization; A Practical Guide, Institution of Chemical Engineers, Rugby, Warwickshire, UK, 1995.

B. T. D. Allen, K. S. Rosselot, Pollution Prevention for Chemical Processes, John Wiley & Sons, Inc., New York, USA 1997.

C. R. S. Gupta, Environmental Engineering and Science, Government Institutes, Rockville, MD,USA, 1997.

D. lectures

Course: Analysis and Modeling of Environmental Processes		
Language: English		
Lecturer: Prof. Bruno Zelić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**3**	**45**
Laboratory	**0**	**0**
Seminar	**3**	**45**
		Overall: 90
		ECTS: 7

PURPOSE:

Application of process models for estimation of parameters and immeasurable states of the process, process optimization, up-scaling of lab-scale model simulation results on the pilot-plant and industrial scale, process control and product quality control.

THE CONTENTS OF THE COURSE:

1st week

Basic concepts about process. Basic definitions for the model. Classification of models: analytical and non-analytical, deterministic and stochastic, distributed and homogeneous, linear and non-linear, static and dynamic.

2nd week

Applications and examples of models. Engineering analysis of physical, chemical, biological and environmental processes – development of process models: scheme of process streams, mass and energy balance, model parameters, numerical methods for model solving, selection of computer programs and simulation software, simulations, model application.

3rd week

Linearization of models. Non-linear models and their steady-states, numerical methods for assessment of steady-states of non-linear systems. Jacobi iterative method, Newton-Raphson method, method of secants.

4th week

Models and simulations of 1st and 2nd order dynamical systems. Analytical solutions.

5th week

Laplace transforms and transfer functions.

6th week

Mathematical methods for solving od differential equations: Euler method, Runge-Kutta method, Rosenbrock method.

7th week

Discretization methods: finite difference method, method of lines, collocation method.

8th week

Estimation of model parameters, linear and non-linear regression analysis: trial and error method, least square method, simplex method, Nelder-Mead method.

1st partial test

9th week

Model sensitivity analysis, stability of solutions. Model simulations.

10th week

Application of model simulation results for optimization, design and control of processes.

11th week

Experimental plan and process optimization: Evolutionary operation (EVOP), genetic algorithm, simplex method, Rosenbrock method.

12th week

Case study 1. Production of pyruvic acid.

13th week

Case study 2. Industrial aerobic waste-water treatment.

14th week

Case study 4. Treatment of air pollution caused by galvanizing industry.

15th week

Case study 4. Transport of pollutant in porous media.

2nd partial test

GENERAL AND SPECIFIC COMPETENCE:

Achieving of basic knowledge needed for solving of case studies - process analysis and modeling using chemical engineering methodology.

KNOWLEDGE TESTING AND EVALUATION:

Continuous grading and evaluation during teaching – 100 points

a) Partial tests (2) – 50 points

b) Project – 35 points

b) Home work (4) – 10 points

c) Class attendance – 5 points

or

Written exam – 100 points

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. E. Holzbecher: Environmental Modeling using Matlab®, Springer-Verlag, Berlin, 2007.
2. J. Mikleš, M. Fiklar: Process Modeling, Identification and Control, Springer-Verlag, Berlin, 2007.
3. Plazl, M. Lakner: Uvod v modeliranje procesov, Univerza v Ljubljani, Ljubljana, 2004.
4. J.B. Snape, I.J. Dunn, J. Ingham, J.E. Prenosil: Dynamics of Environmental Bioprocesses, VCH, Weinheim, 1995.
5. K.T. Valsaraj: Elements of Environmental Engineering, Thermodynamics and Kinetics, Lewis Publishers, Boca Raton, 2000.
6. W.W. Nazaroff: Environmental Engineering Science, John Wiley & Sons, New York, 2001.

Course: Environmental Impact Assessment		
Language: English		
Lecturer: Dr. Sanja Papić, professor Dr. Ana Lončarić Božić, associate professor Dr. Hrvoje Kušić, assistant professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall:30 + 0 + 30
		ECTS: 5

PURPOSE:

Introducing the environmental impact assessment procedure according to the national legal requirements in the filed. Case study of environmental impact assessment within the seminars.

THE CONTENTS OF THE COURSE:

16. **week:** Introduction to EIA. Different types EIA levels and SEA. Legal framework.
17. **week:** Integration of health and sociological aspects in EIA.
18. **week:** Stages of EIA: screening and scoping, identification and evaluation of impacts, determination of mitigation measures, decision making, control, and analysis). Steps after EIA: monitoring, audit, evaluation.
19. **week:** Screening: goals and methods. Examples of positive and negative screening lists. Scoping: results and methods.
20. **week:** 1st partial exam.
21. **week:** Impact identification and evaluation methodology: location description, assessment techniques, environmental components, uncertainties)
22. **week:** Significance concept in EIA process; types of referent values.
23. **week:** Mitigation of impacts; measures and hierarchy.
24. **week:** EIA and project documentation control.
25. **week:** 2nd partial exam.
26. **week:** Environmental assessment procedure. Environmental management tools. National and European legal framework.

27. week: Screening methods: activity lists, case-by case check. Project characteristics, project location, impact types

28. week: Advantages and disadvantages of public participation and requirements for their involvement in EIA. Presentation of EIA study; content and evaluation.

29. week: EIA post-decision monitoring and audit

30. week: 3rd partial exam

GENERAL AND SPECIFIC COMPETENCE:

Acquiring the knowledge on environmental impact assessment (EIA) procedure, with the particular emphasis on the specific elements and requirements for EIA study preparation

KNOWLEDGE TESTING AND EVALUATION:

1. Partial exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

E. Gilpin, Environmental Impact Assessment; Cutting Edge for the 21st Century, Cambridge University Press, Cambridge, UK, 1995.

F. Lectures

Course: Matlab/Simulink		
Language: English language		
Lecturer: **Ph.D. Nenad Bolf, Assist. Prof.**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**1**	**15**
		Overall: 45
		ECTS: 4

PURPOSE:

Instruct the students to use the software package MATLAB / Simulink and its advanced functions for the purpose of implementing chemical engineering calculation, display and analysis of measurement data, modelling and process optimization.

THE CONTENTS OF COURSE:

MATLAB/Simulink high-level language. Work environment and basic operations.

Working with matrices and fields. Data structure and programming.

Simulation of the processes and systems. Methods and tools for simulation.

MATLAB advanced functions. Drawing and graphic display. Two-dimensional and three-dimensional graphics. Animation.

Fundamentals of symbolic computations in MATLAB. The functions of symbolic computation. Examples of linear algebra. Solving symbolic equations. Special functions. Working in a graphical environment.

Processing of measurement data in the Curve Fitting Toolbox. Parametric and nonparametric adjustment.

Linear and nonlinear adjustment procedures. Statistical parameters of quality adjustment.

Spline Toolbox. The implementation and application of regression analysis methods.

Case-study. First partial exam.

System Identification Toolbox. The development of dynamic process models using identification methods.

Parametric and nonparametric identification. Model validation.

System Identification Toolbox graphical interface. Example of identification based on data from industrial processes.

Fundamentals of Simulink. Modelling, simulation and analysis of dynamic systems. Interaction of MATLAB and Simulink.

Simulink graphical environment. Design of the process models, graphic, work with blocks. Analysis of the results of simulations.

Examples of linear and nonlinear systems, continuous and discrete models, hybrid systems.

Solving real-life problems. Results analysis.

Second partial exam.

GENERAL AND SPECIFIC COMPETENCE:

Apply information technology and programming fundamentals. Solve engineering problems by applying available software packages. Apply mathematical methods and software in case-study solving.

Apply advanced features for analyzing and displaying data. Perform symbolic functions and calculations. Process and analyze measurement data using software tools. Develop process models in a graphical user interface using Simulink. Resolve examples of continuous, discrete and hybrid systems.

KNOWLEDGE TESTING AND EVALUATION:

homework and seminars, partial exams, written exams

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student's survey

LITERATURE:

Course material, presentations and simulations on the course web page.

Ž. Ban, J. Matuško, I. Petrović, Primjena programskog sustava MATLAB za rješavanje tehničkih problema, Graphis, Zagreb, 2010.

D. Grundler, T. Rolich, A. Hursa. MATLAB i primjena u tekstilnoj tehnologiji, Sveučilište u Zagrebu, Tekstilno-tehnološki fakultet, Zagreb, 2010.

MATLAB, The Language of Technical Computing, The MathWorks, Inc., 2012

S.T. Karris, Introduction to Simulink with Engineering Applications, Orchard Publications, 2006

Graduate study programme

Course: Bioseparation Processes		
Language: English		
Lecturer: Prof. Bruno Zelić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE:

The goal of the course in downstream processing is to provide an insightful overview of the fundamentals of downstream processing for biochemical product recovery. Emphasis is given to process integration with a system's view to allow the students to understand the impact of change in one unit's operations on others in the process.

THE CONTENTS OF THE COURSE:

1st week
introduction, bioprocesses and classification of bioprocesses, specificity of biological materials, definition and characterization of bioproducts: biomass, extra-cellulat and intra-cellular products, classification of bioseparation processes

2nd week
bioseparation process selection, (1) pretreatment, (2) solid-liquid separation, (3) volume reduction, (4) purification, (5) formulation of biological products

3rd week
methods for pretreatment of biological products, isolation of intra-cellular products, mechanical and non-mechanical methods for breakdown of cell walls, overview of industrially important methods do breakdown of cell walls

4th week
solid-liquid separation of biological products: (1) filtration (vacuum filtration and filter presses), (2) sedimentation, (3) centrifugation (tube, disc and scroll type centrifuge)

5th week
separation of biological products (i): (1) evaporation, (2) distillation, (3) rectification1
1st partial test

6th week
separation of biological products (ii): (1) liquid-liquid extraction (mixer-settler, extraction column, centrifugal extraction), (2) precipitation

7th week

separation and purification of biological products (iiia): (1) microfiltration, ultrafiltration and nanofiltration, (2) dialysis, (3) pervaporation

8th week
separation and purification of biological products membrane processes (iiib): (1) reverse osmosis, (2) electrodialysis

9th week
purification of biological products (i): (1) chromatographic methods: basic concepts, columns and systems, (1) size exclusion chromatography, (2) affinity chromatography, (3) ion-exchange
2nd partial test

10th week
purification of biological products (ii): chromatographic methods: monolithic chromatography

11th week
purification of biological products (iii): crystallization, drying, lyophylization

12th week
alternative bioseparation processes: extraction with supercritical fluids

13th week
formulation of biological products: extrusion, fluidized bed drying. enzyme immobilization, formulation of pharmaceuticals, tableting

14th week
fully integrated separation of bioproducts; methodology and overview of industrial processes

15th week
3rd partial test

GENERAL AND SPECIFIC COMPETENCE:

Methodological approach for separation, isolation and purification od biological products: biomass, intra-cellular and extracellular products.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial test

or

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

7. E. Holzbecher: Environmental Modeling using Matlab®, Springer-Verlag, Berlin, 2007.
8. J. Mikleš, M. Fiklar: Process Modeling, Identification and Control, Springer-Verlag, Berlin, 2007.
9. Plazl, M. Lakner: Uvod v modeliranje procesov, Univerza v Ljubljani, Ljubljana, 2004.
10. J.B. Snape, I.J. Dunn, J. Ingham, J.E. Prenosil: Dynamics of Environmental Bioprocesses, VCH, Weinheim, 1995.
11. K.T. Valsaraj: Elements of Environmental Engineering, Thermodynamics

and Kinetics, Lewis Publishers, Boca Raton, 2000.

12. W.W. Nazaroff: Environmental Engineering Science, John Wiley & Sons, New York, 2001.

Course: Environmental Engineering and Management		
Language: English		
Lecturer: Dr. Ana Lončarić Božić, associate professor Dr. Hrvoje Kušić, assistant professor		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall:30 + 0 + 30
		ECTS: 5

PURPOSE:

Introducing environmental engineering and management issues with the aim to assess sustainable technologies.

THE CONTENTS OF THE COURSE:

31. week: Introduction to environmental engineering..

32. week: Engineering approach to analysis of environmental problems.

33. week: Environmental pollutants. Control of significant environmental impacts (air, water, soil and waste).

34. week: National environmental legislation.

35. week: Noise pollution.

36. week: Heat and light pollution.

37. week: Strategy for odor control.

38. week: 1st partial exam.

39. week: Waste management and treatment technologies.

40. week: Risk assessment and management.

41. week: Cleaner and low-waste technologies.

42. week: Compliance with environmental management systems.

43. week: Public communication principles.

44. week: Integrated environmental management concept.

45. week: 2nd partial exam.

GENERAL AND SPECIFIC COMPETENCE:

Adoption of sustainable development concept in environmental engineering and management practice. Correlation of pollution sources and minimization

opportunities with sustainable technologies. Acquaintance with main legal requirements in environmental protection. Adoption of sustainability principles and tools in environmental protection and management.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1) E.S. Rubin, C.I. Davidson, Introduction to Engineering & the Environment, McGraw Hill, New York, 2001.

G. P. Calow, Blackwell's Concise Encyclopedia of Environmental Management, Blackwell Science, Oxford, 1999.

H. Lectures

Course: Risk Assessment		
Language: English		
Lecturer: **Assoc. Prof. Ana Lončarić Božić, PhD** **Prof. Sanja Papić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE:

Overview of risk assessment concepts. Value of risk assessment in environmetal management.

THE CONTENTS OF THE COURSE:

1st week - Introduction to risk concepts, general categories of risk and methods for quantitatively risk determination.

2nd week - Major components of risk assessment: hazard assessment, dose-response, exposure assessment, risk characterization.

3rd week - Environmental risk assessment and management of chemicals. Predicted environmental concentration (PEC) and predicted no effect concentration (PNEC).

4th and 5th week - OECD/ISO/EU test methods – a vital component of the environmental risk assessment of chemicals. Physico-chemical methods, biodegradation methods, bacterial toxicity methods, aquatic toxicity methods, soil, sediment and avian toxicity test methods. Limitations of OECD and other test methods.

6th week - Procedure of environmental risk assessment according to EU Directives. Assessment factors: aquatic, STP microorganism, sediment, terrestrial.

7th week - Environmental risk management; EU Directives and international agreements which control directly or indirectly the quantities of specific chemicals or chemical classes which may be used in or discharged to the environment; EQU-Environmental Quality Objectives; BATNEEC-Best Available Techniques not Entailing Excessive Cost. Precautionary principle.

8th week – 1st partial exam

9th week – Legal requirements for risk control at industrial sites. Principles and

goals of Seveso III directive;

10th week – Risk assesment elements for major-accidents hazards. Risk matrix as a risk management tool.

11th week – Correlation of waste management activities with specific health hazards and environmental risks. Risk assessment framework for waste landfills; exposure paths.

12th week – Methodology for data collection and analysis within the risk assessment procedure. Qualitative and quantitative methods in risk assessment.

13th week – Application of Bayesian decision theory in quantitative risk assessment. Examples. Development and application of conceptual models. Case studies.

14th week – Logic trees and their application in risk assessment. Risk analysis; examples of event tree and fault tree.

15th week – 2nd partial exam

GENERAL AND SPECIFIC COMPETENCE:

Understanding the basic principles of risk analysis and risk assessment methodologies in ecology. Adoption of methodology for data collection and analysis, and qualitative and quantitative methods in risk assessment.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1) R. E. Hester, R. M. Harrison, Risk Assessment and Risk Management, The Royal Society of Chemistry, Cambridge, 1998.

2) D. T. Allen, D. R. Shonnard, Green Engineering, Prentice Hall PTR, New York, 2002

Course: Environmental protection in petroleum refining		
Language: English		
Lecturer: Full Prof.Katica Sertić-Bionda, PhD.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**2**	**30**
Seminar		
		Overall: 60
		ECTS: 5

PURPOSE:

Application of chemical engineering knowledge of environmental protection in petroleum refining, with the emphasis on new technological solutions. Air, water and land pollution during petroleum and petroleum products transport – potential hazards, emergency measures and environmental cleanup procedures.

THE CONTENTS OF THE COURSE:

1. Introduction to the petroleum refining. The origin, exploration and chemical composition of petroleum.
2. Separation processes of petroleum refining and their products.
3. Conversion processes of petroleum refining and their products.
4. Sulphur compounds in raw materials and products; thermal and catalytic cracking.
5. Aromatic hydrocarbons in raw materials and products; catalytic reforming and isomerisation.
6. Hydrotreating of raw materials and products.
7. Removing of sulphur compounds from refinery gases. Claus process.
8. Air pollution in petroleum refineries; control parameters.
9. Distillation residues refining processes and their impact on the environment.
10. Sources of water pollution in petroleum refineries; control parameters.
11. Wastewater treatment. The impact of pollution on the ground.
12. Effects of petroleum refinery waste streams on water ecosystem.
13. Hydrocarbon fuels; composition and properties.
14. Emissions; the impact of fuel quality. Legislations and regulations.

GENERAL AND SPECIFIC COMPETENCE:

Acquisition of theoretical and applicative knowledge about the impact of petroleum refineries and petroleum products on the environment, as well as methods for monitoring, managing and reducing harmful effects.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment by three tests, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

K. Sertić-Bionda, Petroleum refining, lecture for students (www.fkit.hr).

K. Sertić-Bionda, Petroleum refining, instructions for laboratory practicum (www.fkit.hr).

N. P. Cheremisinoff, P. Rosenfeld, Handbook of pollution prevention and cleaner production: best practices in the petroleum industry, Elsevier Inc., 2009.

J. G. Speight, Environmental Analysis and Technology for the Refining Industry, John Wiley & Sons, Inc., 2005.

Course: RECYCLING AND WASTE MANAGEMENT		
Language: English		
Lecturer: **Prof. Zlata Hrnjak-Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5

PURPOSE:

Introduction to pollution sources, types of pollution, waste characterization and waste management. The concept of organization of solid waste management.

THE CONTENTS OF THE COURSE:

1st week: Introduction. Environmental pollution

2nd week: The "green engineering" - sustainable development

3rd week: Life time assessment (LCA, LCC)

4th week: Units and measures of pollution

5th week: Definition of waste, solid waste characterization

6th week: Morphological composition of solid waste, waste characteristics

7th week: 1st partial test

8th week: The system of solid waste management (collection, storage, segregation, transportation)

9th week: Management of materials from waste by recycling; metal, plastic waste

10th week: Management and recycling; glass, paper, building materials, e-waste

11th week: Management and recycling; hazardous waste, composting

12th week: Management and recycling; mixed waste by burning, hazardous waste in cement kiln

13th week: Municipal waste landfill; choice of location, decomposition of municipal waste, landfill emissions

14th week: Municipal waste landfill; leachate, landfill design, landfill management. The concept of organized solid waste

15th week: 2nd partial test

LAB:

- Recycling of paper

- Recycling of plastic
- visit to the factory of waste management

Seminar: Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students: students will be trained to solve the problems of pollution; introducing the principle of pollution reduction and waste treatment.

Specific competencies are that students will gain knowledge and competencies on the application of principles to reduce pollution, methods of evaluation and assessment of pollution sources and types of pollution or waste technologies for solid waste management and its organization concept.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. James R. Mihelcic, Julie Beth Zimmerman, Environmental Engineering: Fundamentals, Sustainablity, Design, John Wiley& Sons, 2009, United States of America.

2. Nelson L. Nemerow, Franklin J. Agardy, Patrick Sullivan, Joseph A. Salvato, Environmental Engineering; Environmental health and Safety for Municipal Infrastructure, Land Use and Planning and Industry, 6th edition, John Wiley & Sons, 2009. New Jersey.

3. J.Scheirs, Polymer Recycling: Science, Technology and Applications, J.Wiley & Sons, Brisbane, 1998

4. H. Alter, Disposal and Reuse of Plastics, in Encyclopedia of Polymer Science and Engineering, H.F.Mark, N.M.Bikales, C.G.Overberger i G.Menges, , J.Wiley & Sons, New York, 1986, 5, p 103.

5. A. L. Andrady, «Plastics and the Enviroment», J.Wiley & Sons, Hoboken, New Jersey, 2003.

6. A. Azapagic, A. Emsley, I. Hamerton ”Polymers, the Enviromental and Sustanible Development” J. Wiley & Sons, N.Y. 2003.

7. Science Direct, Scirus, Web of Science

Course: Bioremediation		
Language: English		
Lecturer: **Assoc. Prof. Marija Vuković Domanovac, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5,0

PURPOSE: Introduce students to beneficial biodegradation processes for the removal or detoxification of pollutants in soil, water and sediment, and show them into the problem of bioremediation in order to make decisions and action in the field of environmental protection by applying the acquired knowledge.

THE CONTENTS OF THE COURSE:

1st week: Fundamentals of bioremediation

2nd week: Characterization of microorganisms and environmental factors

3rd week: Selection of microbial process for treatment of soil and water

4th week: Biostimulation and bioaugmentation

5th week: In-situ bioremediation

6th week: Ex-situ bioremediation

7th week: 1st partial test

8th week: Bioremediation of oil spills

9th week: Bioremediation of nitroaromatic compounds and chlorinated phenols

10th week: Bioremediation of BTX compounds

11th week: Bioremediation of pharmaceuticals and pesticides

12th week: Microbial removal of ammonia and nitrates from groundwater

13th week: Microbial remediation of metals

14th week: Phytoremediation

15th week: 2nd partial test

GENERAL AND SPECIFIC COMPETENCE: Understanding of the process of bioremediation and selection and adaptation of microorganisms for the efficient degradation of the selected compound.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2) or exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. R.L. Crawford, D.L. Crawford, Bioremediation: principles and applications, Cambridge University Press, 1998.
2. S. McEldowney, D.J. Hardman, S. Waite, Pollution: ecology and biotreatment, Longman Scientific&Technical, Essex, 1993.
3. H.J. Rehm, G. Reed, Environmental Porcesses I, Vol. 11a, Wiley-VCH, Weinheim, 1999.
4. A. Singh, R.C. Kuhad, O.P. Ward, Advances in applied bioremediation, Springer Verlag Berlin Heidelberg, 2009.

Course: Environmental protection in petrochemical industry		
Language: English		
Lecturer: Full Prof. Ante Jukić, PhD.; Assoc. Prof. Elvira Vidović, PhD.		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE:

To familiarize and understand the processes and products of the petrochemical industry, their impact on the environment and integral approach to environmental protection, emphasising the application and development of new technological solutions and processes in accordance with the principle of sustainability.

THE CONTENTS OF THE COURSE:

1. Petrochemical industry: raw materials (crude oil, natural gas, coal, biomass), processes and products - technological, economical, environmental, social and geopolitical influences. Global trends and incentives to reduce environmental impacts.
2. Main chemical reactions and processes of hydrocarbon conversions: mechanisms, thermodynamics, process conditions.
3. Integrated approach to environmental protection in the chemical industry through the concept of best available technology (BAT).
4. Rcycling technologies of used lubricating oil. The quality of re-raffinated oil.
5. Processes of cleaning and processing of natural gas; liquefied natural gas (LNG), liquefied petroleum gas (LPG).
6. Methane as fuel and petrochemical feedstock. Halogenated hydrocarbons.
7. Production of syngas and hydrogen. Economy based on hydrogen.
8. Production of clean fuels (synthetic gasoline and diesel motor fuels) Fischer-Tropsch synthesis: GTL, CTL and BTL.
9. Examples of application of BAT concept: the industrial production of ammonia.
10. Examples of application of BAT concept: production of olefins by steam

cracking and production of polyethylene.

11. Main products based on ethylene, propylene and C4 unsaturated hydrocarbons.
12. Aromatic hydrocarbons (BTX), products; production, the impact on the environment.
13. Sources of pollution of air, water and soil in petrochemical processes, techniques of processing and reducing pollution. Industrial examples: production of styrene and polystyrene, the production of propylene oxide and polypropylene.
14. Reducing the environmental impact of industry by integration the oil processing and production of petrochemicals.

GENERAL AND SPECIFIC COMPETENCE:

The adoption and application of theoretical knowledge on major petrochemical products; including reaction pathways and technological scheme for their production.
The application of the integrated approach to environmental protection and BAT concept in the petrochemical industry.

KNOWLEDGE TESTING AND EVALUATION:

Continuous assessment through the two exams, written or oral exam.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

student survey

LITERATURE:

Ante Jukić, Elvira Vidović: Environmental protection in petrochemical industry, lecture, 2010. (www.fkit.hr)

A. Chauvel i G. Lefebvre: Petrochemical processes - technical and economic characteristics:
Vol. I. Synthesis gas derivatives and major hydrocarbons;
Vol. II. Major oxygenated, chlorinated and nitrated derivatives. Technip, Paris, 2001.

Course: PLASTIC WASTE MANAGEMENT		
Language: English		
Lecturer: **Prof. Zlata Hrnjak-Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5

PURPOSE:

Introduction to polymers and polymer waste, treatment of polymer waste before recycling and recycling technologies.

THE CONTENTS OF THE COURSE:

1st week: Introduction. The application of polymers and waste stream

2nd week: Introduction to Polymer Chemistry - Synthesis of polymers

3rd week: Nomenclature, classification and properties of polymers,

4th week: The miscibility of polymers, homogeneous / heterogeneous polymer waste

5th week: Types of polymer waste

6th week: Share of polymer waste in municipal waste

7th week: 1st partial test

8th week: The main principles of plastic waste management

9th week: Procedures of polymer waste treatment : separation, washing, grinding

10th week: Mechanical recycling: technologies and processing

11th week: Chemical recycling: technologies and processing

12th week: Energy Recovery

13th week: Technologies of incineration

14th week: Recycling of rubber

15th week: 2nd partial test

LAB:

Treatment of plastic waste before recycling
a. separation, b. grinding, c. washing

d. characterization (MFR, DSC, TGA)
Mechanical recycling:
a. extruding - preparation of the pelets
b. injection moulding -preparation of test specimens
c. characterization of recycled materials (mechanical properties, DCS, TGA and FTIR)

Seminar: Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

Students will learn how to select the appropriate technology for recycling and polymer (plastic and rubber) waste management.
Specifically will gain knowledge and competence on certain types of polymers and specific technologies for recycling as well as independent performing the recycling processes and knowledge of polymer waste as a raw material, and acquire competence in the field of plastic waste.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. J. Scheirs, Polymer Recycling: Science, Technology and Applications, J.Wiley Brisbane, 1998.

2. A. L. Andrady, «Plastics and the Enviroment», J.Wiley & Sons, Hoboken, New Jersey, 2003.

3. Adisa Azapagic and al. ,"Polymers, the Enviromental and Sustanible Development" J. Wiley & Sons, N.Y. 2003,

4. N. L. Nemerow, Waste Treatment, in H. F.Mark, N. M. Bikales, C.G. Overberger i G. Menges, Encyclopedia of Polymer Science and Engineering, J.Wiley & Sons, New York, 1989, Vol. 17, str.699.

5. Science Direct, Scirus, Web of Science

Course: Corrosion and environment		
Language: Croatian		
Lecturer: Helena Otmačić Ćurković		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**VIII**
Laboratory	**1**	**VIII**
Seminar	**-**	
		Overall: 3
		ECTS: 5

PURPOSE: The aim of the course is to present corrosion processes, the mechanism and kinetic of corrosion reactions. The influence of corrosion of structural materials on environment and economy is examined. Corrosion protection methods are presented and a special emphasis is placed on those protection methods that pollute the environment. Possibilities for replacing various toxic substances and risky procedures with new non-toxic compounds and procedures that do not present hazard to environment are analyzed.

THE CONTENTS OF THE COURSE:

1.Types and causes of pollution.

2.Corrosion of metals: causes, theoretical background and types of corrosion processes. Dependence of corrosion rate and forms of corrosion damage on environment.

3. Effects of corrosion on environment: influence of corrosion products on environment (water, soil). Endangerment of human lives and environment by the corrosion of structural materials.

4. Importance of adequate corrosion protection and monitoring in various industries: chemical, food, pharmaceutical, oil and gas industry.

5. Corrosion in human body. Corrosion in nuclear power plants and canisters for nuclear waste storage. Corrosion stability of stainless steel in various environment

6. Presentation of student works. Discussion

7. Preliminary exam

8. Visiting industrial facilities related to the corrosion protection

9. Biocorrosion. Increased corrosion in polluted environments.

10. Corrosion protection methods that negatively influence to the ecological system: metal protection by treatment of corrosion medium; environmental compliance of corrosion inhibitors (problem of toxic inhibitors); design and investigation of new non-toxic corrosion inhibitors.

11. Electrochemical methods for corrosion protection: cathodic protection (problem of soluble anodes). Organic coatings (toxic additives to protective coatings; pigments of heavy metals, organic solvents).

12. Protective coatings: problems in surface preparation, metallic coatings (highly toxic electroplating baths);

13. The analysis of possibilities for replacing toxic methods by newly-developed environmentally acceptable corrosion protection methods and practices

14. Presentation of student works. Discussion

15. Preliminary exam

GENERAL AND SPECIFIC COMPETENCE: -Understanding of hazards that corrosion and inadequate corrosion protection present to environment and human health;

- Recognizing how some of the corrosion protection methods may endanger environment and human health due to the release of toxic compounds;

- Ability to determine which corrosion protection method is the most adequate for given corrosion issue;

- Relating presence of pollution and climatic parameters to the corrosion level of various structural materials.

KNOWLEDGE TESTING AND EVALUATION:

Preliminary exam. Oral presentation of seminar papers. Written exams.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Continuous evaluation.

LITERATURE:

1. E.Stupnišek-Lisac i H. Otmačić Ćurković, Korozija i okoliš, interna skripta 2012.

2. E.Stupnišek-Lisac: Korozija i zaštita konstrukcijskih materijala, FKIT, Zagreb 2007.

3. S.K. Sharma: Green Corrosion Chemistry and Engineering, Wiley-VCH, Germany, 2012.

Course: Organic dyes and environment protection		
Language: English		
Lecturer: Prof. Sanja Papić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE:

Introduction to the basic concepts of color, and understanding of the correlation between the chemical structure of organic compounds and their color. Gaining knowledge of the properties, manufacture, application, and environmental and toxicological aspects of the various classes of organic synthetic dyes. Understanding the adverse effects of dyes on human health and the environment. Knowledge about laws and regulations providing health and environmental protection during the manufacture, use and storage of dyes.

THE CONTENTS OF THE COURSE:

1)Basic concepts of color. Empirical correlations between the chemical structure of organic compounds and their color. Industrial applicability of colored compounds.

2)Areas of application of organic dyes (textile dyes, nontextile dyes, functional dyes and optical brighteners)

3)Chemical classes of dyes.

4)Application classes of dyes.

5)Color Index.

6,7)Synthesis methods and basic properties of dyes from selected chemical / application groups

8)Organic pigments: optimization of their syntheses and physical conditioning operations. The impact of crystal structure and particle size on the application properties of pigments.

9,10)Problems of organic dyes in the environment. Specificity of environmental problem of dye-containing waste water and an overview of treatment processes.

11)Food dyes.

12)Toxicological properties of dyes: acute toxicity, sensitization, mutagenicity, carcinogenicity.

13)Metabolism of azo dyes.

14)Activities of ETAD (Ecological and Toxicological Association of Dyes and Pigments Manufacturers) that contribute to the sustainable development of dye industry.

15)Safety Data Sheets and special regulations relevant for dyes.

GENERAL AND SPECIFIC COMPETENCE:

Knowledge on organic synthetic dyes, properties and application areas of different groups of dyes, production, and environmental and toxicological aspects. Competence in solving environmental and health problems arising from the production and use of organic dyes and pigments.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey.

LITERATURE:

1) H. Zollinger, Color Chemistry, VCH, Weinheim, 1987.
2) K. Hunger, Industrial Dyes, Wiley-VCH, Weinheim, 2002.
3) A. Reife, H. S. Freeman, Environmental Chemistry of Dyes and Pigments, John Wiley & Sons, 1996.

Course: Advanced Oxidation Technologies

Language: English

Lecturer: Dr. Sanja Papić, professor

Dr. Ana Lončarić Božić, associate professor

Dr. Hrvoje Kušić, assistant professor

TEACHING	WEEKLY	SEMESTER
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall:30 + 15 + 15
		ECTS: 5

PURPOSE:

Introducing the advanced oxidation technologies for the water purification and wastewater treatment. Acquiring the knowledge on characteristic radical chain reactions, reaction mechanisms, process parameters and reactor systems for particular advanced oxidation process.

THE CONTENTS OF THE COURSE:

46. **week:** Introduction to Advanced Oxidation Processes (AOPs); basic principles, oxidation by free radicals. Types of AOPs, applications and advantages in comparison to conventional water treatment processes.
47. **week:** Homogeneous and heterogeneous Fenton type processes. Basic principles, reaction mechanisms, process parameters, reactor systems, application characteristics. Photo-Fenton processes.
48. **week:** Ozone; characteristics, formation and stability. Direct and indirect mechanism of organics oxidation by ozone.
49. **week:** Ozonation, catalytic ozonation and peroxone process; chemical reactions, reaction mechanism, process parameters, reactor systems and application characteristics. Enhancement of process effectiveness by UV irradiation.
50. **week:** 1st partial exam.
51. **week:** Basic principles of UV irradiation. Absorption and bond energy dissociation. UV light sources and characteristics.
52. **week:** Basic principles of UV photolysis. Molar absorption coefficient and quantum yield. Direct photolysis. Inhibitory effect of water matrix on process effectiveness.
53. **week:** AOPs with UV irradiation; photochemical processes. Typical oxidants and their alternatives. Influence of process conditions and

inhibitory effect of water matrix on process effectiveness.

54. week: AOPs with UV irradiation; photocatalytic processes. Typical catalysts and their alternatives. Influence of process conditions and inhibitory effect of water matrix on process effectiveness.

55. week: 2nd partial exam.

56. week: AOPs based on electrical discharge; basic principles and limitations. High-voltage electrical discharge (corona); the effect of reactor configuration on process chemistry.

57. week: Ultrasonic processes; sono-chemistry principles and acoustic cavitations. Homogeneous and heterogeneous reactions. Reactor configurations. Application of ultrasound in combination with ozone and/or UV irradiation; synergistic and antagonistic effects

58. week: Water radiolysis; basic principles, reactive species formation, and limitations. Reaction kinetics of species formed by water radiolysis and various organic scavengers. Influence of natural organic matter on process effectiveness.

59. week: Different modeling approaches for simulation of AOPs effectiveness. Application of response surface methodology for AOPs optimization. Application of mechanistic modeling for prediction of AOPs efficiency; kinetics and degradation mechanisms.

60. week: 3rd partial exam

GENERAL AND SPECIFIC COMPETENCE:

Acquiring the knowledge on the application of AOPs for water treatment.
Analysis and optimization of AOPs based water treatment technologies.
Application of chemical engineering methodology and analytical procedures for water quality preservation.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. M. A. Tarr, Chemical Degradation Methods for Wastes and Pollutants, Marcel Dekker, New York, 2003.

I. S. Parsons, Advanced Oxidation Processes for Water and Wastewater Treatment, IWA Publishing, London, 2004.

J. Lectures

Course: RECYCLING AND WASTE MANAGEMENT		
Language: English		
Lecturer: **Prof. Zlata Hrnjak-Murgić, PhD**		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5

PURPOSE:

Introduction to pollution sources, types of pollution, waste characterization and waste management. The concept of organization of solid waste management.

THE CONTENTS OF THE COURSE:

1st week: Introduction. Environmental pollution

2nd week: The "green engineering" - sustainable development

3rd week: Life time assessment (LCA, LCC)

4th week: Units and measures of pollution

5th week: Definition of waste, solid waste characterization

6th week: Morphological composition of solid waste, waste characteristics

7th week: 1st partial test

8th week: The system of solid waste management (collection, storage, segregation, transportation)

9th week: Management of materials from waste by recycling; metal, plastic waste

10th week: Management and recycling; glass, paper, building materials, e-waste

11th week: Management and recycling; hazardous waste, composting

12th week: Management and recycling; mixed waste by burning, hazardous waste in cement kiln

13th week: Municipal waste landfill; choice of location, decomposition of municipal waste, landfill emissions

14th week: Municipal waste landfill; leachate, landfill design, landfill management. The concept of organized solid waste

15th week: 2nd partial test

LAB:

- Recycling of paper

- Recycling of plastic
- visit to the factory of waste management

Seminar: Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students: students will be trained to solve the problems of pollution; introducing the principle of pollution reduction and waste treatment.

Specific competencies are that students will gain knowledge and competencies on the application of principles to reduce pollution, methods of evaluation and assessment of pollution sources and types of pollution or waste technologies for solid waste management and its organization concept.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. James R. Mihelcic, Julie Beth Zimmerman, Environmental Engineering: Fundamentals, Sustainablity, Design, John Wiley& Sons, 2009, United States of America.

2. Nelson L. Nemerow, Franklin J. Agardy, Patrick Sullivan, Joseph A. Salvato, Environmental Engineering; Environmental health and Safety for Municipal Infrastructure, Land Use and Planning and Industry, 6th edition, John Wiley & Sons, 2009. New Jersey.

3. J.Scheirs, Polymer Recycling: Science, Technology and Applications, J.Wiley & Sons, Brisbane, 1998

4. H. Alter, Disposal and Reuse of Plastics, in Encyclopedia of Polymer Science and Engineering, H.F.Mark, N.M.Bikales, C.G.Overberger i G.Menges, , J.Wiley & Sons, New York, 1986, 5, p 103.

5. A. L. Andrady, «Plastics and the Enviroment», J.Wiley & Sons, Hoboken, New Jersey, 2003.

6. A. Azapagic, A. Emsley, I. Hamerton ”Polymers, the Enviromental and Sustanible Development” J. Wiley & Sons, N.Y. 2003.

7. Science Direct, Scirus, Web of Science

Course: POLYMER SCIENCE AND TECHNOLOGY		
Language: English		
Lecturer: Prof. Zlata Hrnjak – Murgić, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 4

PURPOSE:

The purpose of the course is to introduce students to polymer science and technology. The knowledge includes polymer processes; bulk, solvent, suspension and emulsion polymerization. Basis of polymer thermodynamics of solubility, degradation, compatibility. Polymers waste management, methods for reducing the volume of plastic waste.

THE CONTENTS OF THE COURSE:

1. Introduction to polymer science. Classification of polymers. Nomenclature of polymers.
2. Chain growth polymerization. Step growth polymerization. Catalysts.
3. Ionic polymerization: anionic and cationic polymerization. Living polymers.
4. Reaction of copolymerization. Lewis-Mayo equation. Typical copolymerization diagrams. Q-e scheme.
5. Ring-opening polymerization.
6. Polymer processes: Bulk polymerization and polymerization in solution. Suspension polymerization. Emulsion polymerization.
7. Reactors in polymer chemistry. Reactions of crosslinking.
8. 1st partial test
9. Polymer Materials; structure –properties relationships
10. Technology of plastics processing
11. Polymer degradation and stability (thermal degradation, oxidative and UV stability)
12. Thermodynamics of solubility, Compatibility of polymers, blends and composites
13. Biopolymers
14. Polymer Waste Management and Sustainable development
15. 2nd partial test

Laboratory:

1. Suspension polymerization of poly(vinyl-acetate)
2. Determination of molecular mass (viscosity)
3. Swelling of rubber
4. Identification of polymers: FTIR spectrophotmetry, TGA, DSC, DMA
5 Extrusion

Seminar:

- Making presentations and / or written seminar paper on a given topic

GENERAL AND SPECIFIC COMPETENCE:

General competencies of students - 1st understanding polymer systems during synthesis, 2nd competence to understanding and analyzing production processes of polymers, 3rd understanding of the basic knowledge of synthesis, structure and properties, and the competence to identify and solve problems in the field of waste plastics.

Specific competencies of students- 1st gaining knowledge about the synthesis of polymeric materials, 2nd understanding the mechanisms of catalytic polymerization process, 3rd knowledge and competence of understanding the basic elements of chemistry and engineering materials related to the chemical composition, structure, manufacturing, properties and applications, 4th knowledge about the basic principles of environmental protection and polymers waste management, 5th ability to independently present the lab results in written and oral form.

KNOWLEDGE TESTING AND EVALUATION:

Partial tests (2 times) (written) or exam (written and/or oral)

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

University of Zagreb student survey

LITERATURE:

1. H. Mark, N. Bikales, C. Overberger, G. Menges, Encyclopaedia of Polymer Science and Engineering, John Wiley & Sons, New York, Vol. 1-17, 1985-1989.
2. Joel R. Fried, Polymer Science and Technology, Prentice Hall Professional, USA, 2003.
3. L.A. Utracki: Polymer Alloys and Blends, Hanser Publishers, New York, 1989.
4. A. L. Andrady, «*Plastics and the Environment*», J. Wiley & Sons, Hoboken, New Jersey, 2003.
5. A. Azapagic, A. Emsley, I. Hamerton ”*Polymers, the Environmental and Sustainable Development*” J. Wiley & Sons, N.Y. 2003.

Course: Environmental engineering project		
Language: English		
Lecturer: Full. Prof. Đurđa Vasić-Rački, PhD Associate prof. Zvjezdana Findrik Blažević, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**1**	**15**
Laboratory	**5**	**75**
Seminar	**-**	**-**
		Overall: 90
		ECTS: 10

PURPOSE: To familiarize students with the fundamentals of process plant design. Mastering the basis of process design in the software package SuperPro Designer using all the knowledge acquired during the studies.

THE CONTENTS OF THE COURSE:

1st week – Introductory lecture. Basic terms of process plant design.

2nd week - Project organization. Basics of process design.

3rd week – Criteria for the location of process plant. Adoption of investment decision. Phases of project realization and work distribution.

4th week - Contracts – regulation of relations between investor and designer.

5th week – Research and process development. Phases of process development. Example from practice – development of industrial process for the production of tert-L-leucine.

6th week – Rating of the process. Feasibility study of the process. Distribution of expenses in production. Financial effect of investment.

7th week - First preliminary exam

8th week – Project assignment.

9th week – Process design. Process scheme. Block scheme. Process flow scheme.

10th week – Mathematical formulation of the problem. Synthesis, optimization and simulation of process schemes.

11th week – Mass and energy balances. Stoichiometry. Systems of linear and non-linear equations. Method of division factors.

12th week - Pipes and instrumentation. Process control and instrumentation. Process safety.

13th week – Detailed process design. Program of the project. Layout of the process plant.

14th week – Auxiliaries and facilities. Environmental Impact Assessment.

15th week - Second preliminary exam.

Parallel with the lectures through the entire semester students work on their project assignments in small teams on computers.

GENERAL AND SPECIFIC COMPETENCE:

Students acquire basic knowledge needed for project development and develop the skill of solving a problem by team work by working in groups.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams
2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. Šef, Olujić: Projektiranje procesnih postrojenja, SKTH/Kemija u industriji, Zagreb 1988

Course: Bioreaction technique		
Language: English		
Lecturer: Associate prof. Zvjezdana Findrik Blažević, PhD Associate prof. Ana Vrsalović Presečki, PhD		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**1**	**15**
Seminar	**1**	**15**
		Overall: 60
		ECTS: 5

PURPOSE: Upgrading of the theoretical knowledge acquired in previous courses in the field of biochemical engineering. Acquiring practical and theoretical knowledge required for the implementation of bioprocesses. Learning computer techniques of experimental data analysis.

THE CONTENTS OF THE COURSE:

1st week - Preparation of heterogeneous biocatalyst-immobilized biocatalysts – methods of immobilization.

2nd week - Methods for characterization of immobilized biocatalysts.

3rd week - Application of immobilized biocatalysts. Industrial processes with immobilized biocatalysts.

4th week - The use of biocatalysts in non-conventional media.

5th week - Stability of biocatalysts. Deactivation of biocatalysts. Models of the biocatalyst deactivation. Methods of biocatalyst stabilization.

6th week - Mathematical modeling of complex reaction systems based on experimental data using a computer (software package SCIENTIST).

7th week – First preliminary exam

8th week - Products obtained by using microbial whole cells. The conditions for the microbial growth. Mechanisms for regulation of metabolism. Characteristics of primary and secondary metabolism.

9th week – Microbial growth kinetics- Monod kinetics. Microbial growth kinetics on multiple carbon sources. The kinetics of substrate consumption and product formation during the cultivation of microorganisms.

10th week - Mass balances (biomass and substrate) of the continuous cultivation of microorganisms. Continuous microbial cultivation with biomass recycle. Continuous cultivation of microorganisms in the multistage bioreactor system.

11th week - Efficiency of microbial processes (yields, conversion, space-time

yield)

12th week - Types of bioreactors. The selection of a bioreactor for microbial cultivation. Aeration. The basic theory of oxygen transfer across gas-liquid interface.

13th week - Techniques of microbial cultivations. Methods for monitoring the bioprocesses.

14th week – Steps in downstream processing for bioproduct recovery from fermentation broth. Methods for biomass separation from fermentation broth. Method of the cell disintegration. Concentration and purification of the bioproduct.

15th week - Second preliminary exam

GENERAL AND SPECIFIC COMPETENCE:

Acquiring basic and advanced knowledge of chemical engineering methodology needed to solve practical problems in biotransformation analysis and implementation of bioprocesses.

KNOWLEDGE TESTING AND EVALUATION:

1. Partial preliminary exams

2. Written exam

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student survey

LITERATURE:

1. J.E. Bailey, D.F. Ollis, Biochemical Engineering Fundamentals McGraw-Hill (1986).
2. A.Scragg ed. Biotechnology for Engineers - Biological Systems in Technological Processes, Ellis Horwood Limited, Chichester, (1988)
3. K. van't Riet, J. Tramper, Basic Bioreactor Design, Marcel Dekker, New York, (1991)
4. H.W. Blanch, D.S. Clark, Biochemical Engineering, Marcel Dekker, New York, (1996)

Course: Industrial Ecology – Graduate study Environmental Engineering		
Language: English		
Lecturer: Felicita Briški		
TEACHING	**WEEKLY**	**SEMESTER**
Lectures	**2**	**30**
Laboratory	**0**	**0**
Seminar	**2**	**30**
		Overall: 60
		ECTS: 5

PURPOSE: To introduce the concept that requires that the industrial system is viewed as part of the environment with proper care of him. It is a system in which one seeks to optimize the total materials cycle from virgin material to finished product and its final disposal.

THE CONTENTS OF THE COURSE:

Lectures:
Week 1: ENVIRONMENT AND ANTROPOSPHERE
Week 2: SOCIAL FACTORS AND ENVIRONMENTAL ETHICS
Week 3: INDUSTRIAL ECOLOGY AND THE LEGAL SYSTEM
Week 4: NATURAL RESOURCES AND THEIR AVAILABILITY
Week 5: INDUSTRIAL SYSTEMS
Week 6: PRINCIPLES OF INDUSTRIAL METABOLISM
Week 7: INDUSTRIAL ECOSYSTEMS
Week 8: 1st partial exam
Week 9: DESIGN AND PRODUCT DEVELOPMENT, CHOICE OF MATERIAL
Week 10: LIFECYCLE OF PRODUCT, PROCESSES AND EQUIPMENT
Week 11: LIFECYCLE ASSESSMENT - priorities and impact analysis
Week 12: INDICATORS AND METRICS
Week 13: DETERMINANTS OF INDUSTRIAL ECOLOGY IN CORPORATIONS
Week 14: IMPLEMENTATION OF INDUSTRIAL ECOLOGY IN CORPORATIONS
Week 15: 2nd partial exam

Seminars: A case study of selected topics related to teaching and writing and presenting a project related to new product development/manufacturing process/ manufacturing equipment. Field work.

GENERAL AND SPECIFIC COMPETENCE: Upon completion of this course students will learn about the role of environmental engineer in the industrial system and how to design an appropriate process or product in accordance with sustainable development. This primarily involves reducing waste during the production cycle and avoiding the use of known hazardous chemical compounds, as well as the application of closed systems for waste streams. They will be able to conduct life cycle assessment of products, processes and equipment. They will know which determinants of industrial ecology are and how to apply them in the factory, corporation or service activity.

KNOWLEDGE TESTING AND EVALUATION: Two partial exams (after certain units of material) that are recognized as passed exam if both positively evaluated, and the written and oral exams within specified examination periods.

MONITORING OF THE COURSE QUALITY AND SUCCESSFULNESS:

Student questionnaire

LITERATURE:

1. Lowe, E.A., Discovering Industrial Ecology, Battelle Press, Columbus, 1997.

2. Gradel, T.E., Allenby B.R., Industrial Ecology, Second Ed., Pearson Education Inc., Upper Saddle River, 2003.