UČNI NAČRT PREDMETA / COURSE SYLLABUS	
Predmet:	KROŽNO GOSPODARSTVO IN UPRAVLJANJE Z ODPADKI
Course Title:	CIRCULAR ECONOMY AND WASTE RESOURCE MANAGEMENT

Študijski program in stopnja **Study programme and level**	**Študijska smer** **Study field**	**Letnik** **Academic year**	**Semester** **Semester**
Varstvo okolja in ekotehnologije, 2. stopnja	Modul: Ekotehnologije	1. in 2.	/
Environmental Protection and Eco-technologies, 2nd level	Module: Ecotehnologies	1st and 2nd	/

Vrsta predmeta / Course type	Modularni predmet / Modular course
Univerzitetna koda predmeta / University course code:	KGUO

Predavanja **Lectures**	**Seminar** **Seminar**	**Sem. Vaje** **Tutorial**	**Lab. vaje** **Laboratory work**	**Teren. vaje** **Field work**	**Samost. delo** **Individ. work**	**ECTS**
20	20	/	/	/	80	4

Nosilec predmeta / Lecturer:	dr. Patricia Jovičević-Klug, dr. Matic Jovičević-Klug, doc. dr. Ilja Gasan Osojnik Črnivec / Patricia Jovičevič-Klug, Ph.D., Matic Jovičević-Klug, Ph.D, Ilja Gasan Osojnik Črnivec Ph.D., Assist. Prof
Jeziki / Languages: **Predavanja / Lectures:**	Slovenščina / Slovenian / Angleščina / English
Vaje / Tutorial:	Slovenščina / Slovenian / Angleščina / English

Pogoji za vključitev v delo oz. za opravljanje študijskih obveznosti:	**Prerequisits:**
Pogojev ni.	No formal prerequisites.

Vsebina:	**Content (Syllabus outline):**
1. Uvod • definicija odpadkov, stranskih proizvodov ter proizvodnih ostankov, vrste, izvori in lastnosti odpadkov, karakterizacija odpadkov • strateške usmeritve in cilji pri ravnanju z odpadki v EU in Sloveniji, • hierarhija ravnanja z odpadki, krožno gospodarstvo • ključna zakonodaja in ukrepi na področju ravnanja z odpadki, • prenehanje statusa odpadkov ter pomen certifikatov krožno pridobljenih materialov 2. Pristopi za preprečevanje in zmanjševanje odpadkov v vsakdanjem življenju in industrijskih dejavnostih • pristop krožnega gospodarstva 9Rs, s poudarkom na »zero waste« pristopom • ponovna uporaba komponent in sklopov; centri ponovne uporabe, popravljalni centri • ločeno zbiranje odpadkov v komunali in industriji • razlikovanje med industrijskimi odpadki in komunalnimi odpadki	1. Introduction: • Definition of waste, byproducts and production residues, types, sources and properties of waste; waste characterisation. • strategic guidelines and goals in waste management in the EU and Slovenia • waste management hierarchy and circular economy • key legislation and policy in the field of waste resource management • • the end of waste status and the importance of certificates for circularly sourced materials 2. Approaches to prevent and reduce waste in everyday life and industry: • aadoption of circular-economy principles, including *"9Rs"* and *zero-waste* strategies that prioritize prevention over disposal • design for reuse and longevity through the recovery, repair, and reintegration of

• tipologija odpadkov in krožni materiali 3. Trajnostni postopki predelave in obdelave odpadkov • tehnološki postopki predelave in reciklaže pomembnih vrst odpadkov (papirja, kovin, stekla, odpadna hrana?, e-odpadki, plastike, gradbenih odpadkov in jalovina, industrijski odpadki, na primeru odvečnega aktivnega blata, rdečega blata, železnih peskov, blata iz procesiranja elektronike itd.), • trajnostne tehnologije za prodobivanje? krožnih materialov: mehanski , fizikalno-kemijski, kemijski, biokemijski in toplotni postopki obdelave odpadkov, MBO obdelava komunalnih odpadkov, energetska izraba in gorivo iz odpadkov. 4. Končni načini ravnanja z odpadki in materiali • varno odlaganje odpadkov (kriteriji za odlaganje, priprava odlagališč, trajnostne tehnologije odlaganja, procesi pri odlaganju, izcedne vode, odlagališčni plin, zapiranje, rekultivacija in ekstrakcija surovin iz odlagališč-ponovna uporaba), • nevarni odpadki, radioaktivni odpadki (kriteriji, glavne skupine, načini ravnanja in nove možnosti uporabe), • novi trendi pri ravnanju z odpadki (prednostni načini ravnanja, čistejše tehnologije (vodikova plazma, indukcija, kataliza, bioleaching), analiza življenjskega cikla izdelkov), • tehno-ekonomski postopki, stroški in državni fiskalni ukrepi (takse) pri ravnanju z odpadki • Celostni postopki recikliranja s poudarkom na uporabi odpadkov kot vir elementov, spojin, polsurovin in materialov za ponovno uporabo	components and assemblies (e.g., reuse hubs and repair centers) • implementation of effective source separation and selective waste collection in both municipal and industrial systems to enable recycling and resource recovery • distinguishing between industrial and everyday waste. • waste and circular materials typology 3. Sustainable Waste Management: Recovery and Treatment Processes • Overview of technological processes for the processing and recycling of major waste streams, including paper, metals, glass, e-waste, plastics, mine tailings and overburden, industrial waste such as red mud, iron sand, electronic waste sludge etc. • Sustainable technologies for processing of circular materials: study of mechanical, physico-chemical, chemical, biochemical, and thermal waste treatment technologies, including mechanical–biological (MB) treatment of municipal waste and the production of fuels derived from waste. 4. End-of-Life Waste and Material Management Methods • Safe waste disposal practices, including disposal criteria, landfill site preparation, sustainable disposal technologies and processes, leachate management, landfill gas control, and landfill closure and post-closure reclamation and extraction of raw materials from waste • Hazardous and radioactive waste management, covering classification criteria, main waste categories, and specialized handling and treatment methods • Emerging trends in waste management, with emphasis on preferred management strategies, cleaner technologies (hydrogen plasma, induction, catalysis, bioleaching), and product life cycle assessment • Techno-economic aspects of waste management, the role of state fiscal instruments such as taxes and fees • Integrated recycling processes with an emphasis on using waste as a source of elements, compounds, semi-raw materials and materials for reuse

Temeljna literatura in viri / Textbooks:

Obvezna:

1. T. H. Christensen, 2010. Solid Waste Technology & Management, Wiley-Blackwell
2. S. van Ewijk, J. Stegemann, 2023. An Introduction to Waste Management and Circular Economy, UCL Press
3. Tchobanoglous, G. and Kreith, F., 2002. Handbook of Solid Waste Management, McGraw-Hill

Priporočena:

1. Mc Dougall, F.R. et al., 2001. Integrated Solid Waste Management, Wiley-Blackwell
2. T. Letcher, D. A. Vallero, 2019. Waste: A Handbook for Management, Academic Press.

Cilji in kompetence:

Predmetno specifični cilji in kompetence:

Posredovati študentom sistematičen pregled nad vrstami odpadkov, viri in vzroki njihovega nastajanja ter načini ravnanja z njimi. Na tej podlagi bo študent razumel širino in problematiko tega področja varovanja okolja oz. virov, ekološke in tehnološke principe ravnanja z odpadki in ponovno uporabo le-teh, bo sposoben povezovanja zakonodajnih zahtev in tehnoloških možnosti za njihovo izpolnjevanje, kritične izbire in ocenjevanja načinov ravnanja z odpadki ob upoštevanju prednostnih načel ravnanja, uporabe informacijsko-komunikacijskih virov in sistemov za pridobivanje podatkov v okviru seminarskih nalog, ter razvil bo spretnosti /veščine pri pripravi in predstavitvi problematike ravnanja s konkretnimi vrstami odpadkov.

Splošne kompetence:

Sposobnost analize tovrstnih problemov, sinteze in oblikovanja rešitev za ponovno izrabo teh tokov oz. odpravo posledic onesnaževanja okolja in izrabe dragocenih materialov ki so vsebovanih v odpadkih.

Objectives and competences:

Subject-specific objectives and competences:

The course aims to provide students with a systematic overview of waste types, their sources, and the factors contributing to their generation, as well as the methods used for their management and reuse. Building on this foundation, students will gain an understanding of the scope and challenges of waste management within environmental protection and resource conservation. They will become familiar with the ecological, technological, and regulatory principles of waste management, and will be able to relate legislative requirements to appropriate technological solutions. Students will develop the ability to critically select and evaluate waste management methods in accordance with priority management principles, effectively use information and communication technologies and data acquisition systems in seminar assignments, and acquire skills in preparing and presenting analyses of specific waste streams.

General competencies:

Develop the ability to analyze waste management challenges and to synthesize and design effective solutions for the reuse of material and energy flows, as well as for the prevention and mitigation of environmental pollution and loss of v valuable material resources caused by waste generation.

Predvideni študijski rezultati:

Znanje in razumevanje:

Študentje bodo ob zaključku tega predmeta imeli znanje o izvorih, oblikah in nevarnostih ključnih tokov odpadkov, potenciale za njihovo ponovno uporabo oz. za onesnaženje okolja. Spoznali in razumeli bodo principe krožnega gospodarstva - trajnostnih postopkov preprečevanja in ravnanja z odpadki, najboljše razpoložljive tehnologije ravnanja z njimi, osnovne inženirske/tehnične pristope za predelavo v reciklabilno obliko oz. za varno odlaganje in zmanjševanje količine odpadkov. Bistveni namen predmeta je seznaniti študente s preventivnimi pristopi, to je s preprečevanjem

Intended learning outcomes:

Knowledge and understanding:

Upon successful completion of the course, students will demonstrate knowledge of the origins, characteristics, and potential hazards of major waste streams, as well as their potential for reuse or contribution to environmental pollution. Students will understand the principles of the circular economy, including sustainable waste prevention and management strategies, best available waste management technologies, and fundamental engineering and technical approaches for waste processing into recyclable materials or for safe final disposal. A core objective of the course is to

nastanka odpadkov pri viru samem in z inženirskimi pristopi za zmanjšanje emisij pri reciklaži ali pripravi neogibnih odpadkov za odlaganje. <u>Prenesljive/ključne spretnosti in drugi atributi:</u> - zbiranje, uporaba in interpretiranje domačih in tujih virov tehnoloških podatkov - zmožnost analize in izbora optimalne rešitve za posamezen obravnavan problem v praksi - pisno in ustno poročanje o tehnoloških rešitvah	familiarize students with preventive approaches—particularly the prevention of waste generation at the source—and with engineering solutions aimed at minimizing emissions during recycling processes and ensuring the environmentally sound treatment of unavoidable waste. Transferable/key skills and other attributes: - Collection, use and interpretation of domestic and foreign technological data sources. - the ability to analyse and select the optimal solution to a particular problem in practice - Written and oral reporting on technological solutions

Metode poučevanja in učenja:	**Learning and teaching methods:**
- Predavanja, interaktivno poučevanje - Individualna seminarska naloga, s konzultacijami - Terenske vaje – ekskurzija	Lectures, interactive teaching - Individual seminar assignment, with consultations - Field exercises – excursion

Načini ocenjevanja:	Delež (v %) / Weight (in %)	**Assessment:**
Pogoj za pristop k izpitu: prisotnost pri predavanjih.		A prerequisite for access to the exam: presence at lectures.
Končna ocena pri predmetu je sestavljena iz		Final evaluation consists
- Pisni izpit	**50**	- Written exam
- Priprava, predstavitev in zagovor seminarske naloge	**50**	- Preparation, presentation and defense of a seminar
Ocenjevalna lestvica: ▪ zadostno 6: 60–67 % ▪ dobro 7: 68–75 % ▪ prav dobro 8: 76–83 % ▪ prav dobro 9: 84–90 % ▪ odlično 10: 91–100 %		Grading scale: ▪ Sufficient D (6): 60–67% ▪ Good C (7): 68–75% ▪ Very good B (8): 76–83% ▪ Very good B+ (9): 84–90% Excellent A (10): 91–100%

Materialni pogoji za izvedbo predmeta :	**Material conditions for subject realization:**
- Predavalnica z multimedijsko opremo	Lecture hall with multimedia equipment

Obveznosti študentov:	**Student's commitments:**
- Izdelava, predstavitev in zagovor seminarske naloge - udeležba na ekskurzijah oz. terenskih vajah	- preparation, presentation and defense of a seminar paper - participation in excursions or field exercises

Izbrani znanstveni članki / Selected scientific papers:

Jovičević-Klug, M., Ma, Y., Jovičević-Klug, P., Prabhakar, J.M., Rohwerder, M., Raabe, D. (2024) Thermal Kinetics and Nitriding Effect of Ammonia-Based Direct Reduction of Iron Oxides. ACS Sustainable Chemistry & Engineering. 2024, vol. 12-11, str. 9882-9896, DOI: 10.1021/acssuschemeng.4c02363

Jovičević-Klug, M., Souza Filho, I.R., Springer, H., Adam, C., Raabe, D. (2024) Green steel from red mud through climate-neutral hydrogen plasma reduction. Nature. 2024, vol. 625, str. 703-709, DOI: 10.1038/s41586-023-06901-z

Jovičević-Klug et al. 2025: Suppression of Cr nanoclusters and enrichments in Fe–Cr based alloys with cryogenic processing for future energy sector

Jovičević-Klug, M., Brondin, C.A., Caretta, A., Bonnekoh, C., Gossing, F., Vogel, A., Rieth, M., McCord, J., Rohwerder, M., Jovičević-Klug, P. (2025) Suppression of Cr nanoclusters and enrichments in Fe–Cr based alloys with cryogenic processing for future energy sector, Journal of Materials Research and Technology. 2025, vol. 36, str. 9262-9273, DOI: 10.1016/j.jmrt.2025.05.176.

Kang, P., Gabrijelčič, M., Krajnc, A., Osojnik Črnivec, I.G., Likozar, B., Sharma, R.K. (2025) Organically functionalized mesoporous silica network for one-pot synthesis of 5-hydroxymethylfurfural from glucose in water. ACS sustainable chemistry & engineering. 2025, vol. 13, iss. 13, str. 4997–5008, DOI: 10.1021/acssuschemeng.4c09579.

Čič, M., Petek, N., Dogša, I., Damjanović, A., Genorio, B., Poklar Ulrih, N., Osojnik Črnivec, I.G. (2025) Sustainable cyclodextrin modification and alginate incorporation: viscoelastic properties, release behavior, and morphology in bulk and microbead hydrogel systems. Gels. 2025, vol. 11, issue 11, 875, DOI: 10.3390/gels11110875.

Levanič, J., Osojnik Črnivec, I.G., Rozman, I., Skrt, M., Štern, A., Žegura, B., Poklar Ulrih, N. (2024) Nano spray-dried particles of in-situ crosslinked alginate and their toxicological characterisation. International journal of biological macromolecules. 2024, vol. 283, issue 2, 137750, DOI: 10.1016/j.ijbiomac.2024.137750.

Warner, N., Osojnik Črnivec, I.G., Rana, V.K., Cruz, M., Scherman, O.A. (2022) A platform approach to protein encapsulates with controllable surface chemistry. Molecules. 2022, vol. 27, iss. 7, 2197, DOI: 10.3390/molecules27072197.

Osojnik Črnivec, I.G., Skrt, M., Šeremet, D., Sterniša, M., Farčnik, D., Štrumbelj, E., Poljanšek, A., Cebin, N., Pogačnik Da Silva, L., Smole Možina, S., Humar, M., Komes, D., Poklar Ulrih, N. (2021) Waste streams in onion production : bioactive compounds, quercetin and use of antimicrobial and antioxidative properties. Waste management. 2021, vol. 126, str. 476-486, DOI: 10.1016/j.wasman.2021.03.033.

Jemec Kokalj, A., Djinović, P., Osojnik Črnivec, I.G., Pintar, A. (2015) The hazard assessment of nanostructured CeO2−based mixed oxides on the zebrafish Danio rerio under environmentally relevant UV-A exposure. Science of the total environment. 2015, vol. 506/507, str. 272-278. DOI: 10.1016/j.scitotenv.2014.10.120.

Osojnik Črnivec, I.G., Jeločnik Pelicon, P., Djinović, P., Pintar, A. (2014) Biogas production from spent rose hips (Rosa canina L.) : fraction separation, organic loading and co-digestion with N-rich microbial biomass. Bioresource technology. 2014, vol. 171, str. 375-383, DOI: 10.1016/j.biortech.2014.08.085.