List of Modules

for the Master's Program

Ecotoxicology - Environmental Pollution Management
(Master of Science)

at the
University Koblenz-Landau,
Campus Landau

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Content

1. Introduction

This list of modules informs about structure, intention and contents of the master's program Ecotoxicology - Environmental Pollution Management (in the following "Ecotoxicology"). It contains descriptions of the modules (chapter 3) and an exemplary curriculum (chapter 4).

The master's program is laid out for four semesters of full-time study with a total amount of 120 credit points (CP). It consists of nine compulsory modules in the field of ecotoxicology with 56 CP, as well as of a Research Project Course (12 CP) and an Applied Module at External Organisation (10 CP). Furthermore, the degree program consists of five optional fields (Applied Environmental Chemistry (ACP), Chemistry (CHE), Applied Ecology (AÖK), Geoecology (GEO), and Socioeconomics & Environmental management (SÖU)) of which two modules have to be chosen (12 CP). The degree program completes with the master thesis with a colloquium (30 CP).

All compulsory modules are taught in the English language. As at least one module from each optional field is taught in English as well, it is possible to complete the whole course in English. However, we recommend foreign students to acquire German language proficiency to follow teaching in German at least partly as well.

2. Intention and Targeted Learning Outcomes of the Master's Program

The master's program provides a competent education in ecotoxicology along with a basic and application-orientated understanding of the fate, distribution, effects, risk assessment and risk management of chemicals in the environment.

The program is based on current ecotoxicological research and provides an insight into neighbouring fields of science with which an interdisciplinary perception and the development of integrative approaches is promoted. On this basis the graduates are able to work independently on ecotoxicological problems and are competent to analyse and interpret these problems. They are also able to present the results to an international professional audience (presentation, publication).

Furthermore, the program enables the graduates to an independent scientific way of work, systemic thinking and prepares in particular for self-dependent and leading activities. Therefore, the graduates are competent for the professionalism in various fields of ecotoxicology (e.g. scientific facilities and research institutes, authorities, offices, ministries on the subject of crop protection and chemical security, industry, consulting enterprises etc.). A special focus is lad on the international orientation of the degree program which qualifies the graduates for an international job market. In addition, the degree program prepares for a doctorate. During their studies the graduates gain the following qualifications:

Knowledge:

- Profound subject-specific environmental, analytical and ecotoxicological knowledge (principles of aquatic and terrestrial ecotoxicology, environmental analysis, methods and regulatory background, monitoring, fundamentals of toxicology, models in ecotoxicology, chemical assessment and management, analytical instruments) as well as detailed ecological knowledge.
- Knowledge of related fields of sciences (Applied Environmental Chemistry, Geoecology, Modeling & Data Science, Socioeconomics & Environmental Management).

Skills:

- Transfer Skills:
  - The acquired knowledge can be used for scientific problem-solving.

- Methodical (Technical/Statistical) Skills:
  - The graduates are familiar with ecotoxicological guidelines, applicable aspects of the Quality Assurance System (GLP) in laboratories and in the field; they are also able to practically apply the fundamental methods and to transfer their knowledge to unknown test systems. Further test systems can be worked out and conducted independently.
  - The graduates are able to select and to apply corresponding statistical test methods.
  - The graduates are able to select and to apply suitable models for current problems and to analyse

complex environmental data.
- The graduates are familiar with the use of Geoinformation Systems (GIS) and its application as a three-dimensional analysis tool in ecotoxicology.

- Scientific Working Method and Way of Thinking:
  - The graduates are able to work independently on scientific, ecotoxicological problems, i.e. to develop a suitable study design, to select corresponding test methods and to interpret and to assess the results statistically using adequate tests.
  - The graduates gain analytical abilities and they are qualified for process analysis, systemic thinking as well as for a goal oriented, structured, efficient working method. They also have a mechanistic understanding.
  - The graduates are able to work interdisciplinary and they have the ability for an interdisciplinary perception.

- Presentation/Publication/Discussion of Scientific Research Results:
  - The degree program imparts the ability to present the research results to an international audience and to discuss the results.
  - The graduates are able to publish their research in scientific journals.
  - The graduates have the ability to examine and to analyse critically scientific results (e.g. papers in scientific journals) and to assess these results on the basis of their profound knowledge.

- Social Skills:
  - The graduates have diplomatic abilities because they know and understand the positions of different stakeholders in ecotoxicology. They are able to mediate discussions between different groups of stakeholders and to reach a consensus.
  - The degree program develops the ability for successful team work (e.g. within projects or teams), to accept and to positively interact with criticism, as well as to identify, to increase and to use synergy effects.
  - The graduates have leadership skills: projects can be structured into tasks which can be distributed competently. The graduates are able to accept interests and suggestions/ideas of the individual staff and to develop further in cooperation with the staff interests and suggestions. They are also able to pass criticism constructively.
  - The graduates have the ability to communicate, in particular in English. They are able to socialise, to have conversations as well as to express their interests/knowledge/results etc. clearly. As a result, they can operate in an international context.

- Professional Work Experiences:
  - The degree program enhances first professional work experiences in the field of research at the university as well as in companies or governmental agencies.

3. Description of Modules

3.1 Compulsory Modules

Module ETX1: Methods in Ecotoxicology

Module name:	**Methods in Ecotoxicology**
Module code:	**ETX1**
Courses:	a) Quality Assurance GLP (1st semester) b) Ecotoxicological Test Methods (2nd semester) c) Assessment and Monitoring of Effects (2nd semester)
Semester:	1st and 2nd Semester
Duration of module	2 semesters
Frequency of offer	annually
Module coordinator:	Dr. Carsten Brühl
Lecturer:	Dr. Carsten Brühl / Dipl.-Umweltwiss. Jakob Wolfram / Prof. Dr. Ralf Schulz
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 2)
Teaching format / class hours per week / group size:	a) Exercise / 1 class hours (block course, total 15 h) / 30 b) Lecture / 2 class hours (block course, total 30 h) / 100 c) Lab exercise / 6 class hours (block course, total 90 h) / 20
Workload: Face-to-face teaching / independent study	a) 15 h / 15 h b) 30 h / 30 h c) 90 h (Teaching in small groups in the laboratory) / 90 h Total: 135 h / 135 h
Credit points:	9 CP
Required prerequisites:	for b) Module ETX2: Principles of Ecotoxicology Module ETX3: Tools for Complex Data Analysis For c) Module ETX2: Principles of Ecotoxicology Module ETX3: Tools for Complex Data Analysis
Recommended prerequisites:	none
Targeted learning outcomes:	The students are familiar with internationally established ecotoxicological test methods and Good Laboratory Practice according to the OECD and get to know the different test systems in terrestrial and aquatic ecotoxicology currently used in the regulatory context. They get informed about the latest developments of guidelines in the testing scheme of the EU and OECD. Standards in developing countries will be discussed. They understand the fundamental characteristics of tiered testing and are able to interpret test results and sources of error. The students develop an understanding for work to be conducted under a quality assurance system and use this to prepare a study plan considering the OECD principles of GLP.

	They are able to perform a laboratory standard test and analyse the results with various statistical procedures. The students are capable to write a study report according to international criteria of test procedures and GLP as required in the registration process of pesticides by authorities around the world.
Content:	a) Quality Assurance GLP: The Basics of Quality Assurance are divided in: An introduction with an overview of different quality assurance systems Definitions, processes and roles under Good Laboratory Practice (GLP) Legal background of GLP OECD guidelines Preparation of a study plan for a GLP study b) Ecotoxicological Test Methods: The theoretical background of test methods in ecotoxicology is presented in the following way: Introduction of test species and tiered testing scheme as currently used under relevant regulation (latest ISO, EPPO and OECD guidelines) Presentation of the Dose-Effect-Relationship and other parameters for statistical analysis of ecotoxicology tests. Regulatory background of tests, design of tiered test system c) Assessment and Monitoring of Effects: The study plan that was prepared in Quality Assurance GLP is used in Assessment and Monitoring of Effects. Laboratory tests are conducted according to OECD protocols in small groups on selected compounds using different tiers. Study results are recorded to the rules of GLP and analysed with appropriate statistical tools. Students get data on other tiers as well as chemical and biological monitoring data from field and make a simple risk assessment to identify uncertainties etc. without knowing before the full environmental risk assessment framework. Results and first interpretation are presented to other students Students write a study report including an assessment of risk.
Study / exam achievements:	Study report (written, oral, or presentation)
Forms of media:	PowerPoint slides, guidelines, laboratory / testing equipment and material
Literature:	Basic reading: ● Newman, M., Clements, W. (2007): Ecotoxicology – a comprehensive treatment. Taylor & Francis, Boca Raton. ● Advanced reading: ● Giesy, J.P. (2010): Aquatic Toxicology Lab Exercise. CRC, Boca Raton. ● Seiler, J.P. (2005): Good Laboratory Practice: The Why and the How. Springer, Berlin. ● Thompson, K.C, Wadhia, K, Loibner, A. (2005): Environmental toxicity testing. Taylor & Francis, New York. ● Literature handed out in the lecture.

	• Lecture script and current guidelines.

Module ETX2: Principles of Ecotoxicology

Module name:	**Principles of Ecotoxicology**
Module code:	**ETX 2**
Courses:	a) Aquatic Ecotoxicology b) Terrestrial Ecotoxicology
Semester:	1st Semester (or 3rd semester for M.Sc. Environmental Sciences)
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Carsten Brühl
Lecturer:	a) Jun.-Prof. Dr. Mirco Bundschuh b) Dr. Carsten Brühl
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 1) M.Sc. Environmental Sciences (O, 1/3)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours / 100 b) Lecture / 2 class hours / 100
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Required prerequisites:	Admission for MSc. study
Recommended prerequisites:	Knowledge in ecology
Targeted learning outcomes:	The students understand the fundamentals of terrestrial and aquatic ecotoxicology, i.e. biological effects of chemicals on the individual level. The students know the basic principles of ecotoxicological effects at the population, community and ecosystem level in aquatic and terrestrial environments. They know the endpoints relevant at the population and community level and which processes are of importance in addition to the individual level. The students are able to identify the potential effects at the population and community level related with the presence of chemicals in the environment. The students are able to identify, suggest and evaluate testing procedures for ecotoxicological effects at the population and community level. They are familiar with international strategies of addressing ecotoxicological problems in nature. Examples include a variety of special cases in developing countries such as e.g. the decline of vultures in India, amphibian decline in Central America, malaria or locust control in Africa. Moreover, risk management strategies will be presented also focussing on the situation in developing countries.

Content:	a) Aquatic Ecotoxicology: ● Characteristics of environmental chemicals and related processes ● Bioaccumulation, Biomagnification ● Acute, chronic and life cycle toxicity ● Effects on individuals, populations and communities ● Ecotoxicological metrics (e.g. EC50, LC50, NOEC) ● Endpoints ● Dose response relationships (linear, non-linear) ● Combined effects (chemical & biological stressor) ● Resistance, recovery, recolonisation ● Mixture toxicity ● Species sensitivity distributions (SSD) ● Mesocosm studies ● Basics of environmental risk assessment b) Terrestrial Ecotoxicology: Identification of pollutants ● Metals ● Pesticides ● POPs ● Entry ways into the ecosystem ● Fate of chemicals ● Assessment of Toxicity (introduction in testing strategies) ● Physiological effects ● Population level effects ● Community level effects ● Direct and indirect effects ● Additional stressors in the agricultural landscape
Study / exam achievements:	Exam and oral presentation
Forms of media:	PowerPoint slides, handouts
Literature:	● Basic reading: ● Newman, M., Clements, W. (2007): Ecotoxicology – a comprehensive treatment. Taylor & Francis, Boca Raton ● Walker, C.H., Hopkin, S.P., Sibly, R.M., Peakall, D.B. (2012): Principles of Ecotoxicology. 4th ed., Taylor & Francis, New York. ● Advanced reading: ● Clements W. (2002): Community Ecotoxicology. Wiley, New York ● Newman M. (2001): Population Ecotoxicology. Wiley, New York.

Module ETX3: Tools for Complex Data Analysis

Module name:	**Tools for Complex Data Analysis**
Module code:	**B2, resp. ETX3**
Courses:	a) Tools for univariate data analysis b) Tools for multivariate data analysis
Semester:	1. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Noel Juvigny-Khenafou
Lecturer:	Dr. Noel Juvigny-Khenafou, Prof. Dr. Ralf B. Schäfer
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (C, 1) M.Sc. Ecotoxicology (C, 1)
Teaching format / class hours per week / group size:	a) Exercise / 2 SWS / 30 b) Exercise / 2,5 SWS/ 30
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 82,5 h Total: 90 h / 112,5 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study Univariate data analysis is required before participation in multivariate data analysis
Recommended prerequisites:	Fundamental knowledge in algebra and calculus as well as descriptive and simple inferential statistics
Targeted learning outcomes:	The students are able to design a study and select corresponding tools for subsequent data analysis. They can link scientific questions to methods of data analysis. They are familiar with different approaches to data analysis including statistical as well as machine learning approaches. The students are able to process research data and apply data analysis tools in a software environment. They know the advantages and disadvantages of the different methods.
Content:	a) Tools for univariate data analysis: ● Overview on data analysis ● Exploratory analysis ● Approaches to data analysis: Statistical and Machine learning approaches ● Simulation-based approaches ● Correlation, regression and analysis of variance ● Statistical inference ● Multiple linear regression modelling ● GLMs ● Supervised classification: CARTs and Random forests b) Tools for multivariate data analysis: ● Ecological distance measures ● Unconstrained ordination and constrained ordination techniques (e.g. PCA, RDA, CCA, NMDS, db-RDA)

	• Algorithm-based and model based multivariate analysis • Multivariate GLMs • Unsupervised classification: Cluster analysis • MANOVA and Permutational MANOVA
Study / exam achievements:	c) Exam (written)
Forms of media:	Libre Office Impress slides, computer, software (R programming language for statistical computing), Panopto videos
Literature:	Basic and advanced reading: • Borcard, D., Gillet, F., Legendre, P. 2018: Numerical Ecology with R. Springer: New York; 2nd edition. • Crawley, M. J. 2012: The R book. Second Edition. Wiley: Chichester. • Field, A., Miles, J., Field, Z. 2012: Discovering Statistics Using R. SAGE Publications Ltd • Fox, J. 2015. Applied Regression Analysis and Generalized Linear Models. 3rd edition. Sage Publications, Thousand Oaks, California. • Harrell F.E. 2015 Regression modeling strategies: with applications to linear models, logistic regression, and survival analysis. 2nd edition. Springer, New York • James, G., Witten, D., Hastie, T., and Tibshirani, R. 2017. An introduction to statistical learning: with applications in R ; Springer: New York. • Kabacoff, R. 2015. R in Action. 2nd edition. Data Analysis and Graphics with R. Manning Publications • Legendre, P., and L. Legendre. 2012. Numerical Ecology. Elsevier, Amsterdam. • Maindonald, J. and J. Braun 2010. Data Analysis and Graphics Using R. Cambridge University Press, Cambridge. • Matloff, N. S. 2017. Statistical regression and classification: from linear models to machine learning. CRC Press: Boca Raton, 2017. • Zuur, A. F., Ieno, E. N. and G. M. Smith 2007. Analysing Ecological Data. Series: Statistics for Biology and Health.

Module ETX4: Effects of chemical stressors I

Module name:	**Effects of chemical stressors I**
Module code:	**ETX4**
Courses:	a) Principles of Toxicology b) Suborganismic and physiological effects
Semester:	1st Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dipl.-Umweltwiss. Jakob Wolfram
Lecturer:	a) Dr. Robert Landsiedel, BASF SE / Dr. Barbara Birk BASE SE / Dipl.-Umweltwiss. Jakob Wolfram b) Jun.-Prof. Dr. Mirco Bundschuh / Dr. Verena Schreiner / Dipl.-Umweltwiss. Jakob Wolfram
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 1)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours / 100 and Lab exercise (total 10h) /10 b) Lecture / 2 class hours / 100
Workload: Face-to-face teaching / independent study	a) 30 h (2*10 lecture, 2*5 lab) / 60 h b) 30 h / 30 h Total: 60 h / 90 h
Credit points:	5 CP
Required prerequisites:	Admission for MSc. study
Recommended prerequisites:	none
Targeted learning outcomes:	a) The students know the basic principles of toxicology and pharmacology. They are aware of the routes and reactions in the metabolism and the mechanisms of cancerogenity. They are able to assess and describe the potential toxicological profile or pharmacological activity of compounds.The students know the theoretical and practical aspects of the most important biochemical-toxicological methods. They are aware of the procedures, applications and sources of errors associated with each method. They are able to select and practically apply suitable methods for a given problem situation. Moreover, the students obtain experience in team-work, literature search and multimedia presentations. b) Students gain further insight into various suborganismic and physiological effects that can occur as a result of stressor exposures in various organism groups. Learning outcomes are exemplified via standard ecotoxicological tests.

Content:	a+b) Principles of Toxicology and Pharmacology: Anatomy, pathology, physiology (birds, fish, mammals) Toxicodynamic and toxicokinetic Mutagenity and cancerogenity Developmental and reproduction toxicology Organ toxicity (histology) Testing procedures in toxicology Principles of hazard assessment Dose-response-relationships Basic epidemiology Toxicology of major substance classes: e.g. metals, aromates, biocides Pharmacology of major substance classes: e.g. analgetics. hormones, narcotics Regulatory requirements (pesticides, chemicals, REACH) Acute, subchronic and long-term studies Alternative test methods Lab exercise Ames Test (Mutagenicity) Biotransformation
Study / exam achievements:	Portfolio (written)
Forms of media:	PowerPoint slides, Laboratory equipment and material, script
Literature:	Basic and advanced reading: ● Boelsterli, U.A. (2007): Mechanistic Toxicology: The Molecular Basis of How Chemicals Disrupt Biological Targets. CRC Press Inc., Boca Raton. ● Hood, R.D. (2005): Developmental and Reproductive Toxicology: A Practical Approach. CRC Pr Inc., Boca Raton. ● Josephy, P.D., Mannervik, B., Josephy, D. (2006): Molecular Toxicology. Oxford University Press, Oxford. ● Stenersen, J. (2004): Chemical Pesticides, mode of action and toxicology. CRC Press, Boca Raton. ● Streibel, B.J., Klaassen, C.D., Watkins, J.B. (2003): Casarett & Doull's Essentials of Toxicology. McGraw-Hill Professional. ● Wallace Hayes, A. (2001): Principles and Methods of Toxicology. CRC Pr Inc., Boca Raton. ● Williams, P.L., Roberts S.M. (2000): Principles of Toxicology: Environmental and Industrial Applications. Wiley & Sons, Weinheim. ● Woolley, A. (2003): A Guide to Practical Toxicology: Evaluation, Prediction and Risk. CRC Pr Inc., Boca Raton.

Module ETX5: Effects of chemical stressors II

Module name:	**Effects of chemical stressors II**
Module code:	**ETX5**
Courses:	a) Chemical Stress Ecology b) Computer/Lab/Field Course
Semester:	1st semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Jun.-Prof. Dr. Mirco Bundschuh
Lecturer:	a) Jun.-Prof. Dr. Mirco Bundschuh b) Jun.-Prof. Dr. Mirco Bundschuh, Prof. Dr. Ralf Schulz, Dr. Carsten Brühl, Dr. Sebastian Stehle, Dipl.-Umweltwiss. Jakob Wolfram
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 1)
Teaching format / class hours per week / group size:	a) Lecture / 2.5 class hours / 30 b) Course / 2.5 class hours (block course, total 37.5 h) / 30
Workload: Face-to-face teaching / independent study	a) 30h / 60h b) 37.5h / 52.5h Gesamt: 67.5h / 112.5h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for MSc. study
Recommended prerequisites:	none
Targeted learning outcomes:	a) In-depth knowledge about the interactions of chemical stressors with various organismic and higher levels and the resulting alteration in ecosystem structure, functioning, and service provision. The course elaborates on ecological stress responses observable in the field and methods of quantifying aforementioned endpoints in preparation of ETX5b. b) Students will be integrated into various ongoing research projects, ranging from theoretical to practical work, depending on the student's preference, ability, and the availability of current research projects at the University of Landau with a focus on chemical stress ecology (see ETX5a). Furthermore, knowledge about correct project planning and execution for aforementioned projects will be obtained, followed by the conduction of actual experiments/theoretical studies and their subsequent data analysis. Generated and analysed results are transformed into publication-level reports to train for future dissemination of environmental research questions

Content:	The content may vary and change over time but is generally related to relevant research questions in the different areas of ecotoxicology. These range from laboratory studies, via outdoor mesocosms or field studies at the landscape level to meta-analytic and data-centric analyses at the national, continental or global scale.
Study / exam achievements:	Portfolio (written or oral)
Forms of media:	PowerPoint slides, Laboratory equipment and material, script
Literature:	● Walker, C.H., Hopkin, S.P., Sibly, R.M., Peakall, D.B. (2005): Principles of Ecotoxicology. Taylor & Francis, New York. Further literature will be announced at the beginning of the course and is dependent of the research project in b)

Module ETX6: Environmental Analysis

Module name:	**Environmental Analysis**
Module code:	**ETX6**
Courses:	a) Advanced Environmental Chemistry b) Monitoring of pollutants
Semester:	1st or 3rd Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Allan Philippe
Lecturer:	a) MSc. Zacharias Steinmetz b) Dr. Allan Philippe
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C,1) a) M.Sc. Environmental Sciences
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours / 100 b) Lab exercises / 2.5 class hours / 7 (block course)
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 37.5h / 52.5h Total: 67.5 h / 112.5 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	a) The lectures build on fundamental university knowledge in physics, chemistry and environmental chemistry b) Experience on handling of common laboratory consumables and devices c) Knowledge on lab safety rules d) Scientific writing skills and basics of data analysis for writing the reports

Targeted learning outcomes:	a) The students gain advanced knowledge about the production, use and effects of various classes of environmental pollutants and their pathways in different ecosystems, and know the current scientific discussion. The students can apply their knowledge on environmental-chemical processes including transfer, transformation and transport of pollutants; they can predict behaviour of organic and inorganic chemicals and judge their relevance for transport, enrichment, toxicity and bioavailability to current scientific problems. The students know the main processes, which are responsible for the transport of mass and energy within environmental systems and across environmental interfaces. They become familiar with the mathematical description of transport, reaction and physicochemical processes and are able to estimate transport and turnover rates in basic applications. b) Practical course on sampling procedures and extraction methods for pollutants followed by chemical analysis using GC- and LCMS.
Content:	a) Advanced Environmental Chemistry: ● Use of chemicals ● Routes of entry in the environment ● Physicochemical properties, structure-activity relationships and parameterization of compound properties of organic and inorganic compound classes on the basis of current physicochemical models ● Chemistry of transfer and transformation processes in compartments soil, water, air and their mathematical description ● Compound classes (POPs, organic pesticides, metals etc.) ● Effects of compound classes in compartments water, soil, air b) Monitoring of pollutants ● Sampling, preparation and treatment of environmental samples (Extraction, enrichment and purification methods) ● Qualitative analysis of major inorganic and organic group of substances ● Acid/base reactions and buffer systems ● Assessment of organic and inorganic pollutants in soil and water samples (Instrumental techniques: LC/GC-MS, DLS, ICP-OES, Spectrophotometry) ● Standard procedures for determining K_{oc}, pK_a reaction rate constant, and attachment efficiency ● Analysis, interpretation and documentation of experimental results ● Measurement principles of LC-MS, GC-MS and ICP-OES including limitations and error estimations for methods.
Study / exam achievements:	a) Written Exam b) Portfolio (written)
Forms of media:	PowerPoint slides, Laboratory equipment and material, independent work in small groups on small research questions
Literature:	Basic and advanced reading:

	• Hites, R. (2007): Elements of Environmental Chemistry. Wiley & Sons, Hoboken. • Schwarzenbach, R.P. (2002): Environmental Organic Chemistry. J. Wiley & Sons, Hoboken. • Walker, C.H., Hopkin, S.P., Sibly, R.M., Peakall, D.B. (2005): Principles of Ecotoxicology. Taylor & Francis, New York. • Merian E., Anke, M., Ihnat, M., Stoeppler, M. (2004): Elements and their Compounds in the Environment - Occurrence, Analysis and Biological Relevance (in 3 Volumes). Oxford, Wiley-VCH. • Further literature will be announced at the beginning of the course

Module ETX7: Molecular Ecology I

Module name:	**Molecular Ecology I**
Module code:	**AÖK4, resp. ETX7**
Courses:	a) Molecular Ecology I b) Phylogenetic and Population Genetic Analysis
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Klaus Schwenk
Lecturer:	Prof. Dr. Klaus Schwenk / Dr. Anne Thielsch / NN Ecotoxicology
Language:	English
Classification within the curriculum: (compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 2) M.Sc. Ecotoxicology (C, 2) M.Ed. Biologie Gymnasium (O, 1-4) 2F-B.Sc. Naturschutzbiologie (O, 4-6)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours (total 30 h) / 100 b) Exercise / 2 class hours (block course, total 30 h) / 30
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Required prerequisites:	
Recommended prerequisites:	None
Targeted learning outcomes:	The students are familiar with major topics in molecular ecology and basic theories of population genetics and phylogenetics. They get an overview of possible methods in molecular ecology and know examples of their application. The students gain practical experience in phylogenetic analysis software and are able to interpret the results. They are able to apply and interpret genetic data in the context of ecotoxicology, i.e. the potential effects of chemicals on genetics
Content:	Principles of molecular genetics Molecular identification of species, individuals and sex Genetic aspects of behavioural ecology Population genetics Evolutionary ecotoxicology, multi generation studies Conservation genetics Genetically modified organisms Analytical methods in molecular ecology and phylogenetics Genetic effects of chemicals, including genomis, proteomics, transcriptomics etc.
Study / exam achievements:	Portfolio (written/oral)
Forms of media:	PowerPoint, Phylogenetic analysis software

Literature:	Basic reading: Beebee and Rowe (2008): An introduction to molecular ecology. Oxford University Press Frankham, Ballou and Briscoe. (2005): Introduction to conservation genetics. Cambridge University Press. Advanced reading: Bromham (2008): Reading the Story in DNA, Oxford University Press. Ankley, G.T., Miracle, A.L., Perkins, E.J. (2007): Genomics in regulatory ecotoxicology. CRC Press Inc., Boca Raton.

Module ETX8: Models in Ecotoxicology

Module name:	**Models in Ecotoxicology**
Module code:	**ETX8**
Courses:	a) Exposure Modeling b) Effect Modeling
Semester:	3rd Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Nanki Sidhu
Lecturer:	Dr. André Gergs / Dr. Wenkui He/ Dr. Carola Schriever/ Dr. Bernhard Jene
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 3)
Teaching format / class hours per week / group size:	a) Exercise / 2,5 class hours (block course, total 40 h) /30 b) Exercise / 2,5 class hours (block course, total 40 h) / 30
Workload: Face-to-face teaching / independent study	a) 37,5 h / 52,5 h b) 37,5 h / 52,5 h Total: 75 h / 105h
Credit points:	6 CP
Required prerequisites:	
Recommended prerequisites:	Basic or solid knowledge of modelling.
Targeted learning outcomes:	The students know the basic principles of models to be used in the exposure or effect assessment in ecotoxicology. They know the restrictions, sources of errors and are able to quantify the uncertainty associated with them. They are able to use models and to identify situations in which a modelling approach can be of help. They gain the ability to independently analyse a problem situation, to apply a suitable modelling approach and to interpret the results obtained.
Content:	a) Exposure Modeling: ● Surface water models ● Soil persistence models ● Groundwater models ● FOCUS approach ● Decision support systems ● Implementation of risk mitigation measures ● Spatially explicit modeling using GIS ● QSAR modeling ● Fugacity models ● EUSES model b) Effect Modeling: ● Population models ● Metapopulation models ● Spatially explicit models

	• Community models • Food web models • Ecosystem models
Study / exam achievements:	Exam (written)
Forms of media:	Projector, computer, software: FOCUS models, EUSES, Canoco, R, MS Access, MS Excel.
Literature:	Will be announced at the beginning of the course. The courses will use up to date online-tutorials and external internet support.

Module ETX9: Risk Assessment and Management

Module name:	**Risk Assessment and Management**
Module code:	**ETX9**
Courses:	a) Risk Assessment and Management of Chemicals b) Environmental Risk Evaluation c) Data Retrieval and IT Expertise for Risk Assessment
Semester:	3rd Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Ralf Schulz
Lecturer:	Prof. Dr. Ralf Schulz / Dr. Jörn Wogram / Dr. Sebastian Stehle / Dipl. Umweltwiss. Jakob Wolfram
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 3)
Teaching format / class hours per week / group size:	a) Seminar / 2 class hours (block course, total 30 h) / 60 b) Seminar / 2 class hours (block course, total 30 h) / 60 c) Seminar / 2 class hours (block course, total 30 h) / 15
Workload: Face-to-face teaching /independent study	a) 30 h / 30 h b) 30 h / 30 h c) 30 h / 30 h Gesamt: 90 h / 90 h
Credit points:	6 CP
Required prerequisites:	Module ETX1: Methods in Ecotoxicology
Recommended prerequisites:	none
Targeted learning outcomes:	The students know the principles of risk assessment and risk management of chemicals in Germany, the EU and internationally. They are aware of the legislative and non-legislative background to risk assessment and risk management, the procedure and the role different stakeholders play. This is presented for the EU and discussed using examples from various developing countries. They are able to evaluate existing data in order to conduct deterministic and probabilistic risk assessments and to derive appropriate risk mitigation strategies at different levels. They are able to apply their knowledge in a risk assessment and a risk management case study taking into consideration economic and societal aspects. They present the results of their risk assessment and risk management case studies using multimedia presentation. Students are introduced to software and other IT-solutions that are commonly used in the field of regulatory risk assessment and ecological evaluations for the registration of chemicals.

Content:	a) Risk Assessment and Management of Chemicals: ● National and international chemical regulations ● REACH ● Aquatic risk assessment ● Terrestrial risk assessment ● Bird and mammal risk assessment ● Toxicity identification evaluation TIE ● Effect-Directed Analysis ● Weight of evidence approach ● Special cases: nanomaterials, genetically modified organisms, toxicity of mixtures, sediment toxicity ● b) Environmental Risk Evaluation: ● Higher tier uncertainty management ● Probabilistic risk assessment ● Landscape level risk management ● Practical risk mitigation strategies ● Economic and societal aspects of risk ● Stakeholders involved in risk decision and management processes ● Risk communication ● Risk management case studies ● Multimedia presentation c) • EUSES • OpenFoodTox • EUCLID • ECOTOX • (Graph) Databases for data at various spatio-temporal scales • and others
Study / exam achievements:	Portfolio (oral, written, or presentation)
Forms of media:	PowerPoint slides, case study outlines, excursions
Literature:	Basic and advanced reading: ● Greim, H., Snyder, R. (2008): Toxicology and Risk Assessment: A Comprehensive Introduction. Wiley & Sons, Chichester. ● Renn, O. (2008): Risk Governance: Coping with Uncertainty in a Complex World (Risk, Society and Policy). Earthscan, London. ● Suter II, G.W. (2006): Ecological Risk Assessment. Lewis Publishers, Boca Raton. ● Van Leeuwen, C.J., Vermeire, T.G. (2007): Risk Assessment of Chemicals: An Introduction. Springer-Verlag Gmbh, Berlin. ● Vincoli, J.W. (1996): Risk Management for Hazardous Chemicals. CRC Press, Boca Raton.

Module AMEO: Applied Module at External Organisations

Module name:	**Applied Module at External Organisations**
Module code:	**AMEO**
Semester:	2nd Semester
Duration of module	8 weeks
Frequency of offer	each semester
Module coordinator:	Dr. Carsten Brühl
Lecturer:	Lecturers and staff of the Institute for Environmental Sciences plus external lecturers or staff from the other institution
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 2)
Teaching format / class hours per week / group size:	Practical training / 300 h, about 8 weeks full time
Workload: Face-to-face teaching / independent study	Seminar/Discussions: 20 h Independent work: 280 h
Credit points:	10 CP
Required prerequisites:	none
Recommended prerequisites:	Knowledge in environmental chemistry, aquatic or terrestrial ecotoxicology and risk assessment
Targeted learning outcomes:	The module AMEO is an eight-week internship, which can be performed at an external university, governmental or industrial research institute in Germany or abroad. The students become familiar with the practice on the job, requirements of the job market and career opportunities and can establish business contacts. They apply, confirm and expand knowledge and competences achieved during their study. Following successful completion, the students are able to plan an applied scientific work package, conduct the work in an external environment and to discuss and evaluate the results based on the relevant literature.

Content:	The students work independently on a research topic at the chosen institution for a total time of about 8 weeks. Following an introductory discussion with the supervisors, the students perform the (research) work on their own and discuss the obtained results regularly with their supervisors. The content depends on the actual research questions in the selected research organisations. Topics or possible positions with a focus on applied research questions will be suggested by the staff of the Institute for Environmental Sciences or maybe suggested by the students. The topics should be directly related to applied problems relevant in these external organisations and should ideally offer the students opportunities to apply their knowledge and skills in areas, which are not the particular research areas at the Institute for Environmental Sciences in Landau. They include, but are not restricted to the following areas: ● Engineering aspects (e.g. hydrology, mitigation techniques) ● Multimedia modeling ● Food web modeling ● Fish, bird or mammal ecotoxicology and risk assessment ● Agricultural sciences ● Socioeconomics ● Specific aspects in regulatory ecotoxicology ● Risk communication, economic or societal aspects Following the practical work, the students write a short report including: ● Exact name of the institution ● Name and matriculation number of the student ● Period and place of the internship ● Short description of the activities ● Concluding evaluation of the personal and general suitability of the internship Moreover, the students are supposed to present their internship in a presentation for all students in order to offer an exchange of information and experiences between the students.
Study / exam achievements:	Certificate, short report, presentation
Forms of media:	PowerPoint slides, handouts, seminar discussions
Literature:	● General ecotoxicological literature ● Specific published papers/guidelines of the respective research organisations on request

Module RPC: Research Project Course

Module name:	**Research Project Course**
Module code:	**RPC**
Semester:	3rd Semester
Duration of module	10 weeks
Frequency of offer	each semester
Module coordinator:	Dr. Carsten Brühl
Lecturer:	Lecturers and staff of the Institute for Environmental Sciences
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 3)
Teaching format / class hours per week / group size:	Practical training / 360 h, about 10 weeks fulltime
Workload: Face-to-face teaching / independent study	Seminar/Discussions: 10 h Independent study: 350 h
Credit points:	12 CP
Required prerequisites:	At least 20 CP obtained, B2/ETX3 passed
Recommended prerequisites:	Knowledge in environmental chemistry, aquatic or terrestrial ecotoxicology and risk assessment
Targeted learning outcomes:	The students work independently on a research topic of the university for a total time of about 10 weeks. The topics depend on the actual research conducted in the various research groups. However, all topics do have an interdisciplinary character covering at least two different disciplines (e.g. chemistry and ecology, or physics and risk assessment). The students submit proposals for topics selected from a list provided by the teaching staff including a time and resource planning as well as an independently conducted literature search. The selected topics will be studied under the guidance of usually two teaching staff members representing the two science disciplines involved. Following an introductory discussion with the supervisor, the students perform the research work on their own and discuss the obtained results regularly with their supervisor. Following the practical work, the students write a report including the theoretical background, the methods used, the results obtained and a discussion of the results based on the relevant scientific literature. The students present and defend the outcome of their work at an oral presentation. Following successful completion, the students therefore are able to plan a scientific work package conduct the work, evaluate the results based on the relevant literature and present the outcomes.

Content:	The content depends on the actual research questions in the research groups associated with the Institute for Environmental Sciences. They include, but are not restricted to the following areas: Chemical experiments in the lab Environmental colloid chemistry Environmental organic chemistry Physical transport or transfer processes of environmental chemicals Ecotoxicological lab tests Ecotoxicological field studies In situ or monitoring work in the field Molecular genetics GIS data analysis Literature reviews Exposure, effect or landscape modeling Assessment or management of risks
Study / exam achievements:	The mark obtained for this module includes the proposal, the practical work itself as well as the report and final presentation/discussion.
Forms of media:	PowerPoint slides, handouts, seminar discussions
Literature:	Specific published papers on the respective research topic

Master Thesis

preModule name:	**Master Thesis**
Semester:	4th Semester
Duration of module:	1 semester
Frequency of offer:	every semester
Module coordinator:	Dr. Carsten Brühl
Lecturer:	Lecturers and staff of the Institute for Environmental Sciences
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (C, 4)
Teaching format / class hours per week / group size:	independent scientific work
Workload: Face-to-face teaching / independent study	about 900 h work totally
Credit points:	30 CP
Required prerequisites:	At least 90 CP obtained
Recommended prerequisites:	none
Targeted learning outcomes:	The students work independently on a research topic in ecotoxicology for a total time of about 6 months. The topics depend on the actual research conducted in the various research groups. However, all topics should have an interdisciplinary character covering at least two different disciplines (e.g. chemistry and ecology, or Physics and Risk Assessment). The topics will be studied under the guidance of at least two teaching staff members representing the two science disciplines involved. Following an introductory discussion with the supervisors, the students prepare a written detailed research proposal including their hypothesis, introductory literature and statistical methods. After discussing the proposal with their supervisors, they perform the research work on their own and discuss the obtained results regularly with their supervisor. Following the practical work, the students write a thesis including the theoretical background, the methods used, the results obtained and a discussion of the results based on the relevant scientific literature. The students present and defend the outcome of their work as an oral presentation. The thesis is graded by two reviewers. Following successful completion, the students therefore are able to independently plan a scientific work package, conduct the work, evaluate the results based on the relevant literature and present the outcomes.

Content:	The content depends on the actual research questions in the research groups associated with the Institute for Environmental Sciences. They include, but are not restricted to the following areas: Chemical experiments in the lab Environmental organic chemistry Ecotoxicological lab tests Ecotoxicological field studies In situ or monitoring work in the field Molecular genetics GIS data analysis Literature reviews, meta-analysis, data aggregation and analysis Exposure, effect or landscape modeling Assessment or management of risks
Study / exam achievements:	Master thesis with colloquium
Forms of media:	PowerPoint, Handouts, Seminar discussions
Literature:	General ecotoxicological literature Specific published papers of the respective research group(s) on request

3.2 Optional modules[1]

Module ACP1: Water Analysis

Module name:	**Water Analysis**
Module code:	**ACP1**
Courses:	a) Laboratory exercise Water Analysis b) Seminar Water Analysis
Semester:	2. Semester
Duration of module:	1 semester
Frequency of offer:	annually
Module coordinator:	Dr. Dörte Diehl
Lecturer:	Dr. Dörte Diehl / Dr. Clara Mendoza Lera
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional;	M.Sc. Environmental Sciences (O, 2) M.Sc. Ecotoxicology (O, 2) 2F-B.Sc. Basisfach Umweltchemie (O, 3/4)
Teaching format / class hours per week / group size:	a) Lab exercise / 3 class hours (block course, total 45 h) / 10 b) Seminar / 1 class hour (block course, total 15 h) / 30
Workload: Face-to-face teaching / independent study	a) 45 h / 75 h b) 15 h / 45 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Modules B3/ETX6 and B2/ETX3 successfully completed.
Recommended prerequisites:	Fundamental knowledge in chemistry and water chemistry (comparable to the lecture “Boden- und Wasserchemie” of the B.Sc. program) and experiences in laboratory work and knowledge in instrumental analysis.
Targeted learning outcomes:	The students learn how to plan and conduct fundamental chemical and physical water analysis. They become qualified to evaluate and document the results of the analysis in an ecological, ecotoxicological and legal context.
Content:	a) Water Analysis (Laboratory exercise): □ Measurement of physical environmental parameters within water bodies □ Organic and inorganic trace analysis in water samples □ Determination of well-established hydrochemical parameters

[1] **Modules/courses with German titles and descriptions (Targeted learning outcomes and Content) are taught in German language**

	b) Water Analysis (Seminar): □ Presentation of the analytical methods and discussion of the results and experiences from a) in a seminar accompanying the lab exercise.
Study / exam achievements:	Portfolio (written)
Forms of media:	
Literature:	Basic and advanced reading: □ Nollet, M.L., De Gelder, L.S.P (2014): Handbook of water analysis. CRC Press, Boca Raton □ Sharma, S.K., Sanghi, R. (2012): Advances in water treatment and pollution prevention. Springer, Berlin. □ Applied water science (2011), Springer, Berlin. □ Günzler, H., Williams, A. (2002): Handbook of Analytical Techniques. Wiley-VCH, Weinheim. □ Current scientific literature

Module ACP2: Biogeochemical Interfaces

Module name:	**Biogeochemical Interfaces**
Module code:	**ACP2**
Courses:	a) Biogeochemical Interfaces b) Environmental Processes at Biogeochemical Interfaces
Semester:	3. Semester
Duration of module:	1 semester
Frequency of offer:	annually
Module coordinator:	Dr. Christian Buchmann
Lecturer:	Dr. Christian Buchmann
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 2) M.Sc. Ecotoxicology (O, 2) 2F-B.Sc. Basisfach Umweltchemie (O, 3/4)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours (block course, total 30 h) / 60 b) Exercise / 3 class hours (block course, total 45 h) / 10
Workload: Face-to-face teaching / Independent study	a) 30 h / 60 h b) 45 h / 45 h Total: 75 h / 105 h
Credit points:	6 CP
Requirements under the examination regulations:	Modules B3/ETX6 and B2/ETX3 successfully completed.
Recommended prerequisites:	Fundamental knowledge in physical chemistry, environmental chemistry, soil sciences and ecotoxicology
Targeted learning outcomes:	The students understand the central role of interfaces for environmental processes such as sorption and transport of environmental contaminants, bioavailability and toxicity. They understand the intense interactions between physics, chemistry and biology. The students gain experience in the analysis of interfacial processes and are competent for independent interdisciplinary process-oriented experiments.

Content:	a) Biogeochemical Interfaces: (I) weak interactions: their principles and relevance in natural systems (II) water: properties, anomalies, function in biogeochemical systems and hydration (III) biopolymers: production, properties and function, (IV) biogeochemical interfaces: soil organic matter, minerals and organisms, pores, sediments, biofilms, aquatic systems (V) dissolved organic matter: properties, function and current models, natural and engineered particles (VI) Physicochemical environmental processes and interfaces: sorption, pollutant mobilization, colloid-facilitated pollutant transport, wetting, capillarity. (VII) Interactions between biology and chemistry:, interactions in natural systems, swelling, diffusion, precipitation, (VIII) abiogenesis: current theories and concepts, implications. b) Environmental processes at biogeochemical interfaces: Independent planning, implementation and evaluation of current research projects and environmental issues-oriented experiments to wetting and contact angle, surface tension, precipitation and crystallization of colloids at biogeochemical interfaces, swelling processes, etc.
Study / exam achievements:	a) Oral Exam b) Written Portfolio
Forms of media:	PowerPoint slides
Literature:	Basic and advanced reading: Butt, H.-J., Graf, K., Kappl, M. (2006): Physics and Chemistry of Interfaces. Wiley-VCH, Weinheim. Schwuger, M.J. (1996): Lehrbuch der Grenzflächenchemie. Georg Thieme Verlag Stuttgart. Israelachvili, J.N. (2011): Intermolecular and surface forces, Elsevier, Amsterdam Current scientific literature

Module ACP3: Current Developments in Environmental Chemistry

Module name:	**Current Developments in Environmental Chemistry**
Module code:	**ACP3**
Courses:	Current Developments in Environmental Chemistry
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Allan Philippe
Lecturer:	Dr. Allan Philippe
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	Project seminar / 4 SWS / 30
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	none
Targeted learning outcomes:	The students are able to conduct scientific literature researches, to choose, find, analyse, present and discuss literature and to work with scientific literature data bases. They are able to become acquainted with new theoretical and practical knowledge, to transfer basic knowledge to specific scientific problems and to discuss on scientific level. The students are able to transfer basic knowledge in chemistry and ecology to specific scientific topics and applications. The students are familiar with environmental-chemical processes in terrestrial and aquatic systems, the physicochemistry behind them, the interactions between the systems and organic and inorganic contaminants and their relevance for transport, enrichment, toxicity and bioavailability.
Content:	Presentation, analysis and discussion of current scientific literature and ongoing research projects on re-use of waste water in agriculture, fate and effects of engineered nanoparticles, soil quality and soil degradation, soil water repellency, sorption of organic and inorganic chemicals on soil particles, suspended matter and colloids, engineered nanoparticles; interactions between contaminants and environment, relation between environmental processes and biological effects of organic chemicals and nanoparticles. The seminar task is to conduct a scientific literature review including data base research in the context of these or related topics.
Study / exam achievements:	Student’s presentation and portfolio
Forms of media:	

Literature:	Basic reading: Evangelou, V.P. (1998): Environmental soil and water chemistry. John Wiley, New York Weiner, E.R. (2000): Applications of Environmental Chemistry. A practical Guide for Environmental professionals. Boca Raton, CRC Press Andrews, J.E., Brimblecombe, P., Jickells, T.D., Liss, P.S. (2003): An Introduction to Environmental Chemistry. Blackwell, Oxford. Advanced reading: Will be announced in the course.

Module CHE1: Organische Chemie für Fortgeschrittene

odule name:	**Organische Chemie für Fortgeschrittene**
Module code:	**CHE 1**
Courses:	a) Vorlesung Organische Chemie 2 b) Projekt Organische Chemie
Semester:	2./3. Semester
Duration of module	2 semesters
Frequency of offer	annually
Module coordinator:	Dr. Katherine Muñoz
Lecturer:	Dr. Katherine Muñoz
Language:	Deutsch
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 2/3) M.Sc. Ecotoxicology (O, 2/3) B.Ed. Chemie (C, 1/2) Zwei-Fach Bachelor, Basisfach und Wahlfach Umweltchemie
Teaching format / class hours per week / group size:	a) Vorlesung / 2 SWS / 80 b) Projekt Organische Chemie / 1 SWS / 15
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 15 h / 75 h Gesamt: 45 h / 135 h
Credit points:	6 LP
Requirements under the examination regulations:	Zulassung zum Masterstudiengang Environmental Sciences oder Ecotoxicology
Recommended prerequisites:	Grundlagen der Organischen Chemie 1 (Teilmodul UC2), möglichst auch die Inhalte der entsprechenden Bachelormodule UC1, UC2

Targeted learning outcomes:	a) Die Studierenden ● haben ein grundlegendes Verständnis organisch-chemischer Zusammenhänge, der Stoffklassen und der Modelle der Organischen Chemie, ● kennen die wichtigsten Konzepte der Reaktionsverläufe der von organisch-chemischen Reaktionen (Substitution, Eliminierung, Addition, Oxidations- und Reduktionsreaktionen, sowie Umlagerungen) ● können Reaktionen deuten und Synthese-Hypothesen formulieren ● kennen ausgewählte Stoffklassen (z.B. Aromaten, Kunststoffe und Proteine) und deren Umwandlungen ● sind in der Lage sach- und fachbezogene Informationen zu erschließen und auszutauschen b) Die Studierenden ● kennen den Ablauf wissenschaftlichen Arbeitens in der organischen/ökologischen Chemie und sind in der Lage, forschungsorientierte Experimente der organischen Chemie aus Hypothesen abzuleiten, zu entwickeln und durchzuführen ● kennen die Grundsätze wissenschaftlichen Publizierens und können über Experimente im Rahmen eines größeren Forschungsprojekts berichten
Content:	a) Grundlegende Konzepte und Arbeitsweisen der Organischen Synthesechemie Synthese wie Retrosynthese von bekannten und unbekannten Verbindungen Reaktionsweisen von organisch-chemischen Substanzen, Abschätzungen von Reaktivitäten anhand von Funktionalisierungen und Substituenteneinflüssen Transfer der Grundlagen in umweltchemische Zusammenhänge, anwendungsbezogene Synthesechemie Vernetzende Reaktionen, Reaktionsmechanismen Transformation funktioneller Gruppen (C-Atom-Heteroatom), Anwendung an praktischen Beispielen Grundlagen zu wichtigen analytischen Methoden Reaktionsmechanismen: Substitution / Addition / Eliminierung / Umlagerung b) Mitarbeit an einem organisch-chemischen Forschungsprojekt hypothesengesteuerte Entwicklung, Durchführung und Auswertung von Experimenten, wissenschaftliches Arbeiten, Publizieren, Literaturrecherche.
Study / exam achievements:	Klausur
Forms of media:	PowerPoint Folien

Literature:	Begleitende Literatur: Bruice P. Y. (2007). Organische Chemie. Addison-Wesley Brückner R. (2009). Reaktionsmechanismen. Spektrum Clayden J., et al. (2013). Organische Chemie. Springer Spektrum Projekt Organische Chemie: Hier wird Literatur entsprechend des Forschungsgebiets angegeben.

Module CHE2: Physikalische Chemie

Module name:	**Physikalische Chemie**
Module code:	**CHE2**
Courses:	a) Grundlagen der physikalischen Chemie b) Übung Physikalische Chemie
Semester:	1./2./3. Semester
Duration of module	2 semesters
Frequency of offer	annually
Module coordinator:	Dr. Jan David
Lecturer:	Dr. Jan David
Language:	Deutsch
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 1/2/3) B.Ed. Chemie (C, 3/4) Zwei-Fach Bachelor, Basisfach und Wahlfach Umweltchemie (C, 3/4)
Teaching format / class hours per week / group size:	a) Vorlesung / 3 SWS / 80 b) Übung / 1 SWS / 30
Workload: Face-to-face teaching / independent study	a) 45 h / 75 h b) 15 h / 45 h Gesamt: 60 h / 120 h
Credit points:	6 LP
Requirements under the examination regulations:	Zulassung zum Masterstudiengang Environmental Sciences oder Ecotoxicology
Recommended prerequisites:	Grundlagen der Chemie
Targeted learning outcomes:	Die Studierenden haben ein grundlegendes Verständnis physikalisch-chemischer Phänomene, kennen die wichtigsten Konzepte der Thermodynamik, Reaktionskinetik, Elektrochemie und Grenzflächenchemie
Content:	Grundlegende Konzepte und Arbeitsweisen der Physikalischen Chemie Mathematische physikalische Grundlagen Thermodynamik und Gleichgewichtslehre Grundlagen und Anwendungen der Elektrochemie Reaktionskinetik Grenzflächenchemie
Study / exam achievements:	Klausur
Forms of media:	PowerPoint Folien, Übungsblätter
Literature:	Peter W. Atkins; Julio de Paula: Physikalische Chemie. Wiley-VCH, Weinheim

Module CHE3: Ecological Chemistry

Module name:	**Ecological Chemistry**
Module code:	**CHE3**
Courses:	a) Seminar Ecological Chemistry b) Project Ecological Chemistry
Semester:	1.-3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Katherine Muñoz
Lecturer:	Dr. Katherine Muñoz
Language:	Englisch
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 1/2) M.Sc. Ecotoxicology (O, 1/2)
Teaching format / class hours per week / group size:	a) Seminar / 1 SWS / 30 b) Project Ecological Chemistry / 1 SWS / 30
Workload: Face-to-face teaching / independent study	a) 15 h / 75 h b) 15 h / 75 h Total: 30 h / 150 h
Credit points:	6 LP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	Fundamentals of Organic Chemistry 1 (submodule UC2), if possible also the contents of the corresponding bachelor modules UC1, UC2
Targeted learning outcomes:	a) The students ● Understand the principles of the ecological chemistry, with focus on release pathways and transformation processes of organic pollutants ● Identify the role of chemical and physical properties to assess occurrence and fate of organic compounds ● Analyze the role of matrix composition and chemical concentration level in assessing environmental occurrence and exposure ● Evaluate chemical reactions and microbial transformations for the prediction of stability, persistence and the occurrence of parent compound and transformation products ● Summarize and apply main concepts of ecological chemistry to assess chemical responses and human-environment chemical interactions b) The students ● Know the principles of scientific research and scientific writing ● Critically analyze the scientific literature and integrate knowledge to independently develop research questions

	and to elaborate scientific hypotheses ● Apply integrated knowledge to design empirical studies in the context of ecological chemistry. ● Discuss primary literature in a group and present scientific evidence in a verbal (presentation) and written (report) form

Content:	Seminar ecological chemistry ● Concepts of ecological chemistry Part A: organic chemical pollutants: Entry pathways, transport and transformation processes ● Concepts of ecological chemistry Part B: Role of chemistry in mediating interactions among organisms in example of chemical defense response ● Introduction to chemical methods to assess occurrence, fate and chemical responses ● Physicochemical and biological properties of organic chemicals in the context of occurrence, fate and effect (interaction among species) ● Introduction to scientific uncertainty for evaluation of environmental concentrations ● Human-environment chemical interactions: chemical diversity, occurrence, monitoring strategies, effects to humans, animals and non-target species Project ecological chemistry: ● Hypothesis-driven development, implementation and evaluation of experiments ● Introduction to scientific research, literature revision, management and evaluation ● Scientific writing and publishing in an interdisciplinary context ● Developing experiment-specific connections between different environmental science disciplines ● Recognition of new thinking strategies and conceptual development of new ideas ● Choice or specification of a topic to be worked on from the field of ecological chemistry in a laboratory and or field experiment
Study / exam achievements:	Module exam (consisting of the topics of the seminar)
Forms of media:	PowerPoint presentations, presentation of the issues to be addressed with discussion (approx. 45 min plus 15 min), interactive dynamic teaching content via an online platform.
Literature:	Literature: An accessible, and complete textbook on this topic is absent, therefore the literature is based on recent relevant papers in ecological chemistry

Module AÖK1: Indicator Organisms

Module name:	**Indicator Organisms**
Module code:	**AÖK1**
Semester:	1.-3. Semester
Duration of module	1-3 semesters
Frequency of offer	every semester
Module coordinator:	Prof. Dr. Martin Entling
Lecturer:	Prof. Dr. Martin Entling / Dr. Jens Schirmel / Dr. Verena Rösch / Dr. Dagmar Lange / Dr. René Sahm
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (O, 1-3) M.Sc. Environmental Sciences (O, 1-3) B.Sc. Umweltwissenschaften (O, 4-6) 2F-B.Sc. Naturschutzbiologie (O, 4-6) M.Ed. Biologie Gymnasium (O, 1-4)
Teaching format / class hours per week / group size	2 practical courses of 2 class hours each (block courses, total 60 h) / 20
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study, basic skills in species determination of plants and animals
Recommended prerequisites:	Basic knowledge in taxonomy and study design
Targeted learning outcomes:	The students understand biological indication (advantages, problems, limitations). Students develop special interest in certain groups of indicator organisms and are able to employ them for landscape planning and scientific study. They are able to sample them in the field and to identify species. The students are capable of data analysis and interpretation and how to draw conclusions on the sampled environment.
Content:	Each single course (à 2 SWS) covers sampling and determination of a particular organism group and interpretation of the data. Each student chooses two such courses. Examples for organism groups: Vegetation, spiders, insects, and breeding birds for terrestrial environments Plankton, macrozoobenthos, fishes, and macrophytes for aquatic environments The results are used to describe local characteristics and to recognize possible stresses
Study / exam achievements:	Two partial exams, depending on the single course one of the following: written exam (60 min), oral exam (30 min), term paper, portfolio, presentation (15 min). The examination type will be determined at the beginning of the course.
Forms of media:	Field guides, field study equipment, PowerPoint slides
Literature:	Literature will be announced in the course

Module AÖK2: Community Ecology

Module name:	**Community Ecology**
Module code:	**AÖK2**
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Carsten Brühl
Lecturer:	Dr. Carsten Brühl
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Ecotoxicology (O, 3) M.Sc. Environmental Sciences (O, 3)
Teaching format / class hours per week / group size	Lecture/ Seminar / 4 class hours / 60
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for MSc. study
Recommended prerequisites:	Solid knowledge in general ecology and statistics
Targeted learning outcomes:	The students understand the various influences on the composition of animal, plant and microbial communities in time and space. They are also capable of assessing and recording a community in the field and become familiar with the data analysis and the relevant literature for the selected community. Case studies are presented for temperate and tropical regions. An introduction in complex tropical ecosystems is given. The students are getting familiar with the current scientific literature and debates. They understand to extract the relevant information of a scientific paper and can form critical thoughts on published studies.
Content:	Structuring influences that form communities (predation, competition, resource use), herbivory, Introduction to pollination biology, Macroecology Examples of communities in ecosystems Field margins, Aquatic habitats, Arid grassland Forest, Tropical forest Wetlands, Estuaries, Marine ecosystems Quantitative recording of communities Statistical community analysis of complex data set using various multivariate methods Reading and summarizing of recent scientific texts
Study / exam achievements:	Portfolio (written)
Forms of media:	PowerPoint slides, Demonstration of methods
Literature:	Current scientific literature Morin, P. (1999): Community Ecology. Blackwell.

Module AÖK3: Quantitative Experimental Ecology

Module name:	**Quantitative experimentelle Ökologie**
Module code:	**AÖK3**
Semester:	2. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Mirco Bundschuh
Lecturer:	Dr. Mirco Bundschuh, Dipl.-Umw. Jakob Wolfram
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 2) M.Sc. Ecotoxicology (O, 2)
Teaching format / class hours per week / group size:	Laborübung / 4 SWS (Block, gesamt 60 h) / 5
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 LP
Requirements under the examination regulations:	
Recommended prerequisites:	Keine
Targeted learning outcomes:	Students are able to apply their knowledge on ecological and population biological concepts into practice. They gain hands-on experience in experimentation, quantitative data analysis, literature research and writing reports.
Content:	Using a basic ecological concept, students develop a testable hypothesis and an appropriate study design to test it. The case study is used to demonstrate aspects vital to study design and the conduct of experiments: such as suitable controls, replication, independence, and randomisation. The gained data will be analysed and interpreted using appropriate tools. Finally, the students write a report of high linguistic and scientific quality (publication-level) considering the available scientific literature.
Study / exam achievements:	Studienarbeit
Forms of media:	PowerPoint, computer, field and lab methods
Literature:	Literature: ● Karban, R., Huntzinger, M. (2006): How to do ecology: a concise handbook. Princeton University Press. ● Scheiner, S.M., Gurevitch, J. (2001): Design and analysis of ecological experiments. Oxford University Press. ● Hairston, N.G. (1989): Ecological experiments: purpose, design, and execution. Cambridge University Press.

Module AÖK5: Molecular Ecology II

Module name:	**Molecular Ecology II**
Module code:	**AÖK5**
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Anne Schrimpf
Lecturer:	Dr. Anne Schrimpf
Language:	German, optional English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	Lab exercise / 4 class hours (block course, total 60 h) / 6
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Module AÖK4: Molecular Ecology I Module B2: Tools for Complex Data Analysis
Recommended prerequisites:	Basic knowledge in community ecology
Targeted learning outcomes:	The students gain practical experiences with molecular-biological lab methods. They are practiced to interpret population-genetic data and to provide conclusions regarding the long-term population dynamics and the potential factors of influence. The students are able to develop a scientific question, to choose and to apply adequate molecular-biological methods as well as to evaluate their results under application of appropriate statistical procedures.
Content:	During this course the application of technologies of the molecular biology is practiced, to show the effect of environmental factors on the genetic diversity within and between populations. Using a concrete example the population structure and genetic diversity is determined to draw conclusions on the long-term population dynamics. The training period encloses among other things the following methods: DNA-Extraction Gel-electrophoresi s PCR-based methods (RAPD, Microsatellite analysis, sequencing, real-time PCR)
Study / exam achievements:	Term paper (Studienarbeit)
Forms of media:	Laboratory equipment, computer and analysis software, PowerPoint slides
Literature:	laboratory script

Module AÖKE: Land Use and Ecosystems

Module name:	**Land Use and Ecosystems**
Module code:	**B4, resp. AÖKE**
Courses:	a) Ecoregions and land use b) Anthropogenic Ecosystems
Semester:	1. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Hermann Jungkunst
Lecturer:	Prof. Dr. Hermann Jungkunst / Prof. Dr. Martin Entling / Dr. Jens Schirmel
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (C, 3) M.Sc. Ecotoxicology (O, 3) a) Master Ed. Geographie (O, 7-8) b) M.Ed. Biologie Gymnasium (O, 1-4)
Teaching format / class hours per week / group size:	a) Seminar / 2 class hours / 60 b) Lecture / 2 class hours / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	none
Targeted learning outcomes:	Students know the ecoregions of the world. They understand the geoecology of the different regions: global pattern of climate, soil, hydrology, vegetation and fauna and complex correlations between them. They know about typical regional land-use and the sensibility of the system towards human impact. Students understand the ecology of anthropogenic ecosystems. They know the various interactions between biodiversity and human land-use (e.g. agriculture, forestry) and are able to identify synergies and conflicts. Students have an overview of research methods in applied ecology and understand scientific publications.

Content:	a) Ecoregions and land use: The ecozones of the world are presented focussing on global pattern of and complex correlations between - climate, - soils, - hydrology, - vegetation and fauna. Anthropogenic use and the sensibility of the systems including ideas concerning the future development are demonstrated and elaborated on the basis of several case studies. b) Anthropogenic Ecosystems: Ecological processes in agriculture, grassland and urban ecology: plant-environment relationships, populations, interactions, communities and ecosystem services. Applied ecology in practice: biocontrol, agri-environment schemes, control of invasive species, creation of habitat analogues, organic farming, agricultural intensification, energy
Study / exam achievements:	Written exam; presentation in a) (study achievement)
Forms of media:	PowerPoint slides
Literature:	Basic reading: Schultz, J. (2008): Die Ökozonen der Erde. UTB, Stuttgart. (also available in English “The Ecozones of the World” Chapin, F.S. et al. (2013): Principles of Terrestrial Ecosystem Ecology. Springer, New York. Own literature search Advanced reading: Canadell et al. (2007): Terrestrial ecosystems in a changing world. Springer.

Module GEO2: Applied Geoecology I

Module name:	**Applied Geoecology I**
Module code:	**GEO2**
Courses:	Geoecological Field Course
Semester:	2. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Hermann. Jungkunst
Lecturer:	Prof. Dr. Hermann. Jungkunst
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M. Sc. Environmental Sciences (O, 2) M. Sc. Ecotoxicology (O, 2)
Teaching format / class hours per week / group size:	Field exercise / 4 class hours (block course 60 h) / 20
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	Pedological and geomorphological basic knowledge
Targeted learning outcomes:	The students acquire the most important geoecological field methods and the ability of transfer from theory to praxis. They get to know geoecological methods, get the ability to do practical field and group work.
Content:	Fundamental field survey methods are carried out on the basis of a certain theme in a specific region: Pedological field survey (soil and sediment identification, sampling, drawing) Geomorphological field survey (topographic survey, field mapping) Vegetation Analyses (structure, composition, Ellenberg Indicators) Land use mapping Hydrological and microclimatic measurements and field mapping
Study / exam achievements:	Term paper (Studienarbeit)
Forms of media:	Field work
Literature:	Basic and advanced reading: Barsch, H., Billwitz, K. u. H.-R. Bork [Hrsg.] (2000): Arbeitsmethoden in Physiogeographie und Geoökologie. Klett-Perthes, Gotha und Stuttgart. Birkeland, P. W. (1999) Soils and Geomorphology. Oxford University Press, N.Y. Gabler, R.E., Petersen, J.F., Trapasso, L.M. (2007) Essentials of Physical Geography. Brooks Cole.

Module GEO3: Applied Geoecology II

Module name:	**Applied Geoecology II**
Module code:	**GEO3**
Courses:	Project Seminar Geoecology
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Hermann Jungkunst
Lecturer:	Prof. Dr. Hermann Jungkunst
Language:	German or English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M. Sc. Environmental Sciences (O, 2) M. Sc. Ecotoxicology (O, 2)
Teaching format / class hours per week / group size:	Project seminar / 4 class hours (block course, total 60 h) / 20
Workload: Face-to-face teaching / independent study	60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study
Recommended prerequisites:	Basics in the fields of physical geography, ecology, and GIS
Targeted learning outcomes:	The students shall learn the methods to measure and analyse geoecological parameters in the field or laboratory. In contrast to Applied Geoecology I (GEO2), there will be an abiotic focus particularly on biogeochemical fluxes (e.g. greenhouse gases). They should be able to summarize, discuss and present the results. Practical work will focus on methods to understand natural processes and their relationships to human influences. Students will get experience in field and/or laboratory skills.
Content:	Content and methods will vary on focused field and/or laboratory methods in the field of geoecology (e.g. soil analyses, geomorphic or hydrologic measurements).
Study / exam achievements:	Term paper (Studienarbeit)
Forms of media:	PowerPoint slides
Literature:	Depending on topic and focused methods.

Module GEO4: Geosysteme

Module name:	**Geosysteme**
Module code:	**GEO4**
Courses:	a) Prozesse in Agrarökosystemen I b) Prozesse in Agrarökosystemen II
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dipl.-Umweltwiss. Jakob Wolfram
Lecturer:	Prof. Dr. Roland Kubiak, Dipl.-Umweltwiss. Jakob Wolfram, Prof. Dr. Ralf Schulz
Language:	Deutsch
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M. Sc. Environmental Sciences (O, 3) M. Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Vorlesung / 2 SWS / 100 b) Seminar / 2 SWS / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Gesamt: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Zulassung zum Masterstudiengang
Recommended prerequisites:	Grundkenntnisse in Statistik, Umweltchemie, Ökotoxikologie, Bodenkunde und GIS.
Targeted learning outcomes:	Die Studierenden bekommen einen vertieften Einblick in die relevanten Prozesse in Agrarökosystemen. Sie verstehen, wie diese Systeme funktionieren und es wird ihnen anhand der gängigen Konzepte verdeutlicht, wie Agrarökosysteme durch den Menschen genutzt werden können. Das Wissen wird durch ein eigenständiges weitergehendes Literaturstudium und Präsentation im Seminar vertieft.
Content:	a) Prozesse in Agrarökosystemen I: ● Aufbau und Eigenschaften ● Nutzungskonzepte ● Anthropogene Eingriffe ● Agrarökosysteme als Produktionsstandort für Nahrung und Energie ● Anthropogene Eingriffe: Exposition, Wirkungen, Untersuchungsmethoden ● Systemanalyse von Agrarlandschaften b) Prozesse in Agrarökosystemen II: ● Seminar zu den o.g. Themen
Study / exam achievements:	Portfolio (schriftlich)
Forms of media:	PowerPoint Folien
Literature:	Wird in der Veranstaltung bekannt gegeben

Module GEO5: Landschaftsplanung

Module name:	**Landschaftsplanung**
Module code:	**GEO5**
Courses:	a) Raum- und Landschaftsplanung b) Umweltplanung
Semester:	2. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dipl.-Umweltwiss. Jakob Wolfram
Lecturer:	Dr. Jürgen Ott
Language:	Deutsch
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M. Sc. Environmental Sciences (O, 3) M. Sc. Ecotoxicology (O, 3) B. Ed. Geographie (C, 3)
Teaching format / class hours per week / group size:	a) Seminar / 2 SWS / 60 b) Seminar / 2 SWS / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Gesamt: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Zulassung zum Masterstudiengang
Recommended prerequisites:	Keine
Targeted learning outcomes:	Die Studierenden verstehen Grundlagen und Aufgabenbereiche der Raumordnung, Landes- und Umweltplanung und beherrschen die Fachterminologie. Die Rahmenbedingungen, gesetzlichen Hintergründe und Verfahren der Landes- und Umweltplanung sind den Studierenden bekannt. Konkreter in- oder ausländischer Raum kann unter raum- bzw. umweltplanerischen Aspekten analysiert, Planungsentwürfe und -konzepte erstellt sowie kritisch analysiert und mögliche Alternativen aufzeigt werden.
Content:	a) Raum- und Landschaftsplanung: ● Planungen zur Entwicklung, Ordnung und Sicherung des Raumes auf Landes-, Bundes- und EU-Ebene, Raumplanerische Zusammenarbeit zwischen Gebietskörperschaften innerhalb von und zwischen Staaten ● Raumplanerische Konzepte in der Bevölkerungs-, Wirtschafts-, Siedlungs- und Infrastrukturentwicklung, Fachplanungen und Planungsebenen ● Nationale und internationale Planungen im Vergleich, Planungskonzepte, Planungsziele, Planungsinstrumente, Planungsverfahren ● Ökologische Dimension von Planung, Raumanalyse als Grundlage von Planung, Zielkonflikte von Planungen b) Umweltplanung: ● Kartierungen (Kartengrundlagen, Maßstäbe, Koordinationssysteme, Luftbilder), Biotische Kartierungen

	(Methoden, Material) ● Population Vulnerability Analysis (PVA), Fauna-Flora-Habitat-Richtlinie (FFH-R), Fauna-Flora-Habitat-Verträglichkeitsprüfung (FFH-VP), Wasserrahmenrichtline (WRRL) ● Umweltverträglichkeitsprüfung (UVP),
Study / exam achievements:	Klausur
Forms of media:	PowerPoint Folien, Gesetze und Verordnungen
Literature:	Wird in der Veranstaltung zur Verfügung gestellt

Module GEO6: Soil Chemistry

Module name:	**Soil Chemistry**
Module code:	**GEO6**
Courses:	a) Soil Chemistry b) Soil Analysis
Semester:	2. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Dörte Diehl
Lecturer:	Dr. Dörte Diehl
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M. Sc. Environmental Sciences (O, 3) M. Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Seminar / 1 class hours / 30 b) Laboratory Exercises / 3 class hours / 10
Workload: Face-to-face teaching / independent study	a) 15 h / 30 h b) 45 h / 90 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Modules B3/ETX6 and B2/ETX3 successfully completed.
Recommended prerequisites:	Fundamental knowledge in chemistry and soil chemistry (comparable to the lecture “Boden- und Wasserchemie” of the Bachelor course programme) Experiences in laboratory work and fundamental knowledge in instrumental analysis
Targeted learning outcomes:	The students know and understand the soil chemical processes and their relevance for soil quality, soil development, as well as for the transport, bioavailability and toxicity of contaminants. The knowledge of instrumental analysis is deepened. The students are able to plan and perform a soil chemical analysis (nutrients, soil parameters and contaminants) and to evaluate and judge the analysis result in the ecological context as well as in the context of current environmental laws.

Content:	a) Soil Chemistry: Chemical processes of soil development Mobilization and precipitation of soil components Sorption, ion exchange Sesquioxides, soil redox processes and their role for mobilization and immobilization of nutrients and pollutants Relation between speciation, bioavailability, toxicity and mobilization Discussion of the current status and experiences in the laboratory exercises b) Soil Analysis: Case-oriented investigation of a location for contaminants and soil chemical parameters Methods of soil chemical analysis, contaminant analysis including planning, sampling, sample preparation, enrichment, purification Techniques of sequential extraction for inorganic and organic compounds, instrumental analysis and sum parameters Advanced knowledge of chromatography and spectrometry ● Evaluation of analysis results in the ecologic and legislative context
Study / exam achievements:	Portfolio (written)
Forms of media:	
Literature:	Basic and advanced reading: Current soil chemical literature Appelo, C.A. J., Postma, D. (1994): Geochemistry, groundwater and pollution. Balkema, Rotterdam. Alfred R. Conklin Jr. (2005): Introduction to Soil Chemistry. Wiley.Cresser, M.S., Kilham, K., Edwards, A. (1993) Soil Chemistry and its Applications. Cambridge Univ. Pr. Sparks, D.L. (2008) Environmental soil chemistry. Acad. Press. György F. (1999) Soil Chemistry: Processes and Constituents. Akadémiai Kiadó. Foth, H.D. (1990) Fundamentals of soil science. Wiley. Foth, H.D., Ellis, B.G. (1997) Soil Fertility. Lewis.

Module SÖU2: Environmental Policy and Law

Module name:	**Environmental policy and law**
Module code:	**SÖU2**
Courses:	a) European environmental law – legislation, implementation and perspectives b) Current developments in environmental law and policy
Semester:	2./3. Semester
Duration of module	2 semesters
Frequency of offer	annually
Module coordinator:	Prof. Dr. Oliver Frör
Lecturer:	Prof. Dr. Hannes Kopf / Prof. Dr. Oliver Frör
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 2/3) M.Sc. Ecotoxicology (O, 2/3)
Teaching format / class hours per week / group size:	a) Lecture / 2 SWS / 100 b) Seminar / 2 SWS / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 LP
Requirements under the examination regulations:	Admission to M.Sc. study
Recommended prerequisites:	
Targeted learning outcomes:	a) This course focuses on the following questions: ● What are the legal grounds for EU environmental policy and what principles are directives and regulations based upon? ● To what extent does EU environmental regulation more preclude stringent national environmental standards? ● What social and economic challenges have to be overcome? Relevant aspects will be discussed based on actual cases und law suits. b) Current developments in environmental law and policy: Students will be acquainted with the theory and practical examples of domestic and international environmental law and policy and will learn to critically analyze real cases.

Content:	a) European Environmental Law (starting winter 2016/17): ● Development of European Environmental Law ● General Principles of Union Law in relation to Environmental Protection, Art. 191 TFEU ● Legal Basis, Scope of Harmonization, Implementation –The Duty to transpose Environmental Directives into National Law ● Legal Protection – The Direct Effect of Union Environmental Law b) Current developments in environmental law and policy: ● In this seminar current topics of domestic and international environmental law and policy will be independently researched, a term paper will be written and presented orally. In this process, analytical as well as team skills, communication behavior and ability to present will be trained.
Study / exam achievements:	Term paper and presentation (module examination)
Forms of media:	Powerpoint
Literature:	Literature will be indicated in class

Module SÖU3: Environmental Life Cycle Assessment

Module name:	**Environmental Life Cycle Assessment**
Module code:	**SÖU3**
Courses:	a) Environmental Life Cycle Assessment b) Project seminar LCA
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually *(currently not offered)*
Module coordinator:	Prof. Dr. Oliver Frör
Lecturer:	Dr. Jens Peters / Dr. Stefan Jergentz
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Lecture/ 2 SWS / 60 b) Project seminar / 2 SWS / 20
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Gesamt: 60 h / 120 h
Credit points:	6 LP
Requirements under the examination regulations:	Admission to M.Sc. study
Recommended prerequisites:	Module B5/SÖUE
Targeted learning outcomes:	The students learn the basics about life cycle assessment (LCA) and the underlying methodologies. They develop an awareness of the need for life-cycle thinking and the relevance of the different life cycle stages for the total environmental impact of a product or process. The students can use the corresponding LCA software (openLCA / GEMIS) and are able to create LCA and material and energy flow studies independently even for complex application cases. The underlying methods and databases are familiar and can be chosen adequately according to the context and the aim of the study. The results of an LCA study can be interpreted critically and can be presented clearly and comprehensively also to non- expert stakeholders. The students are able to identify environmentally relevant aspects of technical processes and can point relevant improvement potentials. They can interpret and critically review existing LCA studies and are able to evaluate the environmental friendliness of a product.

Content:	- The students learn the basics about life cycle assessment (LCA) and the underlying methodologies. They develop an awareness of the need for life-cycle thinking and the relevance of the different life cycle stages for the total environmental impact of a product or process. The students can use the corresponding LCA software (openLCA / GEMIS) and are able to create LCA and material and energy flow studies independently even for complex application cases. The underlying methods and databases are familiar and can be chosen adequately according to the context and the aim of the study. The results of an LCA study can be interpreted critically and can be presented clearly and comprehensively also to non-expert stakeholders. The students are able to identify environmentally relevant aspects of technical processes and can point relevant improvement potentials. They can interpret and critically review existing LCA studies and are able to evaluate the environmental friendliness of a product.
Study / exam achievements:	a) Exercises (study achievements) b) Project paper and presentation (module exam)
Forms of media:	Powerpoint
Literature:	Accompanying Literature: · H. Baumann, A.M. Tillman: The hitchhiker's guide to LCA. Studentlitteratur, Lund. 2004. ISBN-10: 9144023642 · W. Klöpffer, B. Grahl: Ökobilanz (LCA). Ein Leitfaden für Ausbildung und Beruf. Wiley-VCH, Weinheim, 2009. ISBN: 978- 3-527-32043-1 · J-A. Böning: Methoden betrieblicher Ökobilanzierung. "Hochschulschriften", Metropolis. Band 16, Marburg, 1995. ISBN-10: 3895180149 · EC-JRC, “ILCD Handbook: General Guide for Life Cycle Assessment - Detailed guidance,” European Commission - Joint Research Centre. Institute for Environment and Sustainability, Ispra, Italy: EC-JRC - Institute for Environment and Sustainability, 2010. J.B. Guinée et al. LCA - An operational guide to the ISO-standards. Final Report. Centre of Environmental Science, Leiden University (CML), 2001

Module SÖU5: Environmental Cost-Benefit Analysis

Module SÖU5: Environmental Cost-Benefit Analysis Module name:	**Environmental Cost-Benefit Analysis**
Module code:	**SÖU5**
Courses:	a) Economic valuation and cost-benefit analysis b) Special topics in environmental CBA
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Oliver Frör
Lecturer:	Prof. Dr. Oliver Frör
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours / 60 b) Project seminar / 2 class hours / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for M.Sc. study, basic knowledge in microeconomics
Recommended prerequisites:	Successful participation in module B5/SÖUE
Targeted learning outcomes:	The students achieve the qualification for conducting environmental economic analyses (such as cost-benefit analyses) and for solving decision problems within the public and business context. They gain insights into the theory and practice of preference-based valuation methods. Thereby, they will acquire the ability, to create a well-founded basis for decision making, both under certainty and uncertainty/ risk.
Content:	a) Economic valuation and cost-benefit analysis □ Basics of economic welfare theory □ Structure of environmental economic valuation analyses □ Requirements for measures of well-being □ Measures of well-being according to Marshall und Hicks □ Empirical valuation methods □ Cost-benefit analysis in practice b) Special project in environmental CBA □ Student groups will jointly work on a methodical and policy paper regarding environmental valuation in a selected country.
Study / exam achievements:	a) Exercises (study achievement) b) Term paper (Modulprüfung)

Forms of media:	Powerpoint presentations, Exercises
Literature:	Basic and advanced reading: Will be announced in class

Module SÖUE: Environmental Economics

Module name:	**Environmental Economics**
Module code:	**B5, resp. SÖUE**
Courses:	a) Environmental and Resource Economics b) Special topics in environmental economics
Semester:	1. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Prof. Dr. Oliver Frör
Lecturer:	Prof. Dr. Oliver Frör
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Sciences (C, 1) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Lecture / 2 class hours / 100 b) Seminar / 2 class hours / 60
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission for MSc. study
Recommended prerequisites:	Basic knowledge in business and classical economics
Targeted learning outcomes:	The students gain an understanding of the interaction between economic processes and the environment and learn the principles of an economically optimal use of natural resources. They can apply the theoretical approaches to analyse the impact of economic activities (consumption, production, resource use) on the environment and the welfare of society.
Content:	● The relationship between the economy and the environment ● Market failure, Pareto optimum ● External effects, public goods, property rights ● Instruments of environmental policy ● Practical examples of implemented policy instruments ● Intertemporal decision making ● Discounting and time preference ● The cake-eating model ● The optimal use of non-renewable resources ● The optimal use of renewable resources
Study / exam achievements:	Seminar paper in b), study achievement in a)
Forms of media:	PowerPoint Slides
Literature:	● Field, B.C. (2008), Natural Resource Economics: An Introduction, 2nd edition, Waveland Press, Long Grove, Illinois ● Hackett, S.C. (2006), Environmental and Natural Resource Economics: Theory, Policy and the Sustainable Society, 3rd edition, M.E. Sharpe, Armonk, New York

Module MOD1: Environmental Modeling II

Module name:	Advanced Data Science
Module code:	**MOD1**
Courses:	a) Geoinformation Systems (GIS) Application b) Environmental Modelling II
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Mira Kattwinkel
Lecturer:	Dr. Nanki Sidhu / Dr. Mira Kattwinkel
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Science (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Project Seminar / 2 class hours (block course: periodical project meetings and final presentations) / 30 / Online seminar / 2 class hours / 30* b) Exercise / 2 class hours / 30 / Online lecture / 2 class hours / 30*
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 30 h / 60 h Total: 60 h / 120 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission to the M.Sc. program
Recommended prerequisites:	Course: Umweltmodellierung I (MSI2), Solid knowledge in GIS
Targeted learning outcomes:	a) GIS Application: The students are able to handle, analyse and visualise heterogeneous geospatial- and environmental data as well as to work independently in the context of an environmental research question. b) Environmental Modelling II: The students become familiar with different modelling approaches and apply them in exercises and own projects.
Content:	a) GIS Application: In the context of a (self chosen) project, the students work on complex environmental problems with the help of GIS. This may include: ● Collection and handling of data (e.g. remote sensing images, ATKIS, LIDAR, external databases) ● Modelling and analysis (e.g. geostatistics, calculation of landscape metrics) ● Visualisation (e.g. map design, export into web-applications, virtual 3-D design) b) Environmental Modelling II:b) Advanced Problems in Data Science: In the first part of the course, the students develop and discuss theoretical solutions for selected data analysis problems. In the second part of the course, they apply the tools and knowledge acquired in the module during an own project.

	Overview of ecological modelling System Dynamic models/differential equation models Matrix population models Individual-based models and cellular automata Spatial ecological modelling
Study / exam achievements:	Project with presentation
Forms of media:	PowerPoint slides, computer, software (PostGIS, GRASS GIS, QGIS, Vensim, R, Netlogo, spreadsheet calculations), Panopto videos*
Literature:	Basic and advanced reading: ● Jopp, F., Reuter, H., Breckling, B. (2011): Modelling complex ecological dynamics. Springer: New York, NY. ● Jørgensen, S. E., Fath, B. D. (2011): Fundamentals of ecological modelling. 4. ed.; Elsevier: Amsterdam [u.a.]. ● Petzoldt, T., Rinke, K. (2007): simecol: An Object-Oriented Framework for Ecological Modeling in R. Journal of Statistical Software, 22, (9), 1-30. ● Stevens, M. H. (2009): A Primer of Ecology with R. In Springer-Verlag New York: New York, NY. ● Hengl, T. (2009): A Practical Guide to Geostatistical Mapping, 2 nd ed. University of Amsterdam, 291 p. ● Neteler, M., Mitasova, H. (2008): Open Source GIS: A GRASS GIS Approach, 3 rd ed. Springer. 406 p. ● Obe, R., Hsu, L. (2011): PostGIS in Action. Manning Publications, p. 425.

Module MOD3: Advanced Data Science

Module name:	Advanced Data Science
Module code:	**MOD3**
Courses:	a) Data Science Tools b) Advanced Problems in Data Science
Semester:	3. Semester
Duration of module	1 semester
Frequency of offer	annually
Module coordinator:	Dr. Noel Juvigny-Khenafou
Lecturer:	Dr. Noel Juvigny-Khenafou, Prof. Dr. Ralf B. Schäfer, Dr. Mira Kattwinkel, Dr. Nanki Sidhu
Language:	English
Classification within the curriculum: (Compulsory or optional, semester) [C = compulsory; O = optional]	M.Sc. Environmental Science (O, 3) M.Sc. Ecotoxicology (O, 3)
Teaching format / class hours per week / group size:	a) Exercise / 2 class hours / 30 b) Project Seminar / 2 class hours / 30
Workload: Face-to-face teaching / independent study	a) 30 h / 60 h b) 15 h / 75 h Total: 45 h / 135 h
Credit points:	6 CP
Requirements under the examination regulations:	Admission to the M.Sc. program
Recommended prerequisites:	Tools for complex data analysis
Targeted learning outcomes:	a) Data Science Tools: The students know and can apply current tools for modern data science. They have the ability of retrieving, handling, pre-processing and analysing complex data sets from the social and natural sciences. Moreover, they are capable of setting up a computer environment and workflow for a data analysis problem from scratch. b) Advanced Problems in Data Science: The students can reproducibly solve a complex data science problem during an own project. They know and can apply different solutions and approaches to typical data analysis research questions. They can automate repeated steps in the workflow, rendering the analysis more reproducible and efficient compared to manual handling.

Content:	a) Data Science Tools: ● Overview of software tools for data science ● Version control and joint software development using github ● Creating reports and websites with (R)markdown ● Dynamic data analysis with R, markdown and knitr ● Automated processing using the Shell ● Scraping data from the internet ● Relational databases for spatial and non-spatial databases (PostgreSQL, PostGIS) ● Parallel computing and working with servers ● Specific approaches of data analysis: Bayesian statistics, Generalized and linear mixed models, Artificial neural networks and Deep learning, Non-linearity and GAMs, Advanced tools for multivariate analysis b) Advanced Problems in Data Science: In the first part of the course, the students develop and discuss theoretical solutions for selected data analysis problems. In the second part of the course, they apply the tools and knowledge acquired in the module during an own project.
Study / exam achievements:	Project with presentation (Module exam), a) Successful completion of exercises (Study achievement)
Forms of media:	Presentation slides, tutorials, computer, software
Literature:	Basic and advanced reading: ● Gandrud C. (2014) Reproducible research with R and R Studio. CRC Press/Taylor & Francis Group, Boca Raton. ● Goodfellow I., Bengio Y. & Courville A. (2016). Deep learning. The MIT Press, Cambridge, Massachusetts. ● Haddock S.H.D. & Dunn C.W. (2011) Practical computing for biologists. Sinauer Associates, Sunderland, Mass. ● Matloff N.S. (2016) Parallel computing for data science: with examples in R, C++ and CUDA. CRC Press, Boca Raton. ● Obe, R., Hsu, L. (2011): PostGIS in Action. Manning Publications. ● Zarrelli G. (2017) Mastering Bash: automate daily tasks with Bash. Packt Publishing.

4 Exemplary Curriculum

	1. Semester	2. Semester	3. Semester	4. Semester
	ETX 1: Methods in Ecotoxicology		ETX 8: Models in Ecotoxicology	Master thesis (30 LP)
	Quality Assurance GLP (1 LP)	Ecotoxicological Test Methods (2 LP)	Exposure Modeling (3 LP)	
	ETX 2: Principles of Ecotoxicology	Assessment and Monitoring of Effects (6 LP)	Effect Modeling (3 LP)	
	Aquatic Ecotoxicology (3 LP)	ETX 7: Molecular Ecology I		
	Terrestrial Ecotoxicology (3 LP)	Molecular Ecology I (3 LP)	ETX 9: Risk Assessment & Management	
	ETX 3: Tools for Complex Data Analysis	Molecular Analysis (3 LP)	Risk Assessment and Management of Chemicals (2 LP)	
	Study Design and Univariate Statistical Approaches (3 LP)	AMEO (10 LP)	Environmental Risk Evaluation (2 LP)	
Pflicht-bereich	Multivariate and Multivariate Statistical Approaches (3 LP)		Data Retrieval and IT Expertise for Risk Assessment (2 LP)	
	ETX 4: Effects of chemical stressors I		RPC (12 LP)	
	Principles of Toxicology (3)			
	Suborganismic and physiological effects (2)			
	ETX5: Effects of chemical stressors II			
	Chemical Stress Ecology (3 LP)			
	Computer/lab/field course (3 LP)			
	ETX 6: Environmental Analytics			
	Pollutant dynamics (3 LP)			
	Monitoring of pollutants (3 LP)			
Optional	-	Optionales Modul 1 (6 LP)	Optionales Modul 2 (6 LP)	-
Summe LP	30	30	30	30