Complete course description

Course title: **Remediation of Contaminated Soils**

Course responsible
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Period and points
An intensive master course (NIMC) that will run fulltime over the weeks 32-34. Passing the exam results in 5 ects.

Exam
Running examination based on active course participation and adequate solving of three thematic problems on soil remediation. The two first problems require written individual answers, while the last problem is addressed by an oral presentation at course end by a group of 3-5 students. All three problems must be adequately answered. The three problems are weighted equally (1/3) at exam. Exam evaluation is pass/fail with no second examiner.

Educational background
The course addresses environmentally interested students with basic knowledge in chemistry, mathematics, biology and soil science corresponding to the knowledge achieved through participation in bachelor courses in these disciplines at Nordic agricultural universities/faculties.

Uptake limits
The number of students on the course has an upper limit of 25 students and a lower limit of 10 students, i.e. implementation of the course requires a minimum of 10 students.

Course content
Thousands of soils in Denmark and other Nordic countries as well as globally are contaminated by heavy metals, hydrocarbons (oil, PAH, PBC etc.) and/or other toxic compounds originating from atmospheric deposition, metal mining and processing, oil extraction and use, agriculture, waste deposition and other human activities. As these contaminants pose a risk to human health and ecosystem functioning, the contaminated soils must be remediated. Several soil remediation techniques exist but this course will concentrate on giving the students comprehensive, state-of-the-art understanding and knowledge of potentials and limitations of the most important methods including phytoremediation, bioremediation and soil washing in relation to climatic conditions and soil type as well as source and type of contamination.

The behavior of different contaminants in various soils and the influence of soil contamination on human health and ecosystem functioning leading to various soil and water quality criteria will be overviewed. Interactions between different contaminants and soil types, and the factors determining the interactions including contaminant origin and chemistry, soil composition and characteristics and climatic conditions will be outlined. The risk for adverse effects on human

health and ecosystem deterioration by various soil contaminants will be shortly covered. Current soil and water quality criteria and their strengths and weaknesses will be discussed.

The most important soil remediation methods including bioremediation, phytoremediation and soil washing will be presented and explained. Bioremediation is based on microbial degradation of organic contaminants and focus will be on degradation of various oil types (heating oil, jet fuel, diesel, crude oil) at the polluted site (in-situ) and the possibilities for stimulating degradation rate and efficiency. However, experience with microbial degradation of other organic aliphatic and aromatic hydrocarbons (e.g. PAH, PCB), hormones and pesticides will be examplified. Phytoremediation is in-situ remediation by means of plants and comprises phytoextraction and phytostabilization. By phytoextraction the contaminant, typically heavy metals in moderate concentrations, is extracted (taken up) by the plant and translocated to above-ground biomass, which is harvested and further treated, e.g. burnt. Phytostabilization is used to stabilize the site (soil) against wind and water erosion in order to prevent spreading of the pollution. The importance of plant tolerance to various pollutants as well as there capacity to take up the various contaminants and translocate the pollutants to above-ground biomass will be explained. Examples of plants able to tolerate and take up much higher pollutant concentration than other plants, so-called hyperaccumulators, will be presented. Soils that are too contaminated to be left in place, must be excavated and cleaned in a soil deposit (ex-situ). In the deposit, organic pollutants are typically removed by bioremediation, while heavy metals that are non-degradable must be removed. Cleaning of soils with high contents of heavy metals is often done by soil washing, where the soil is extracted by means of an aqueous solution containing a strong complexing agent. Typically polycarboxylic acids such as EDTA and NTA are used but focus will be on the possible replacement of such synthetic, rather expensive and toxic chemicals by cheap natural compounds such as soluble humic substances in order to promote environmentally friendly soil remediation.

Nordic dimension

This new course is very relevant as a NOVA course because of its transnational and Nordic dimension but also because of its multidisciplinary approach (chemistry, microbiology, pedology, soil science etc.) that aims to give a coherent and comprehensive coverage of practical solutions to an important and widespread environmental problem. Currently remediation of contaminated soils is not addressed in a context but rather given (if at all) as fragments (examples) in a number of courses with other main focuses. The Nordic countries cover a broad range in climatic conditions, soil types and contaminant sources and contents. Thus, temperature changes from temperate over boreal to arctic conditions when going from south to north and the precipitation rate decreases dramatically from western to eastern Scandinavia. Nordic soils exhibit great variability in composition and development including very sandy over loamy to clayey soils formed on mainly glacial deposits and volcanic materials and comprising shallow, poorly developed as well as rather deep, well developed soils; in addition to mineral soils, organic soils (peats soils) are frequently found, especially in the northern part of Scandinavia. Human activities such as metal mining and processing, wood impregnation, waste dumping and intensive agriculture have resulted in highly polluted sites in some parts of the Nordic countries, while almost unpolluted soils can be found in other areas, especially in the northern part of the region.

By including the whole North in the course rather than a single country, many more different remediation scenarios can therefore be covered and illustrated. As a NOVA course linked to the SoilSoc network, the course can draw upon experience and expertise of teachers at all Nordic agricultural universities/faculties. In fact, the course will not be limited to Nordic conditions but

will address soil contamination globally, as some of the SoilSoc teachers are very familiar with environmental issues outside Scandinavia, e.g. in the tropics. Improved recruitment of students is an additional advantage of making it a NOVA course. It should be kept in mind that this is a new course on a subject that is expected to attract a limited number of students in each country but with students from all Nordic and Baltic countries probably supplemented by students from outside the Nordic-Baltic region, the course is expected to be viable. Furthermore, launching of a soil remediation course now is considered timely as soil quality and improvement of degraded soils receive emergent interest in these years, which for instance is indicated by the EU Soil Framework Directive.

Course teaching
The course will run over three weeks (weeks 32-34). The teaching will be a mixture of distant learning and confrontation teaching (classroom teaching) at KU-LIFE. During the first 1.5 course weeks, the students must read and be acquainted with the course materials and solve problems formulated by the teachers. In the last 1.5 weeks, where students will meet with the teachers at KU-LIFE, a mixture of lectures, problem solving and excursions will be used. During this period, groups of 3-5 students must prepare a PowerPoint presentation on a given remediation problem/case. On the last course day, all groups must present their oral presentations and all course participants should take active part in discussions of the presentations of the other groups.
The course responsible will act as teacher throughout the course assisted by other SoilSoc teachers that will cover special issues such as microbial degradation of organic pollutants, remediation of contaminated volcanic soils, remediation of permafrozen soils and soil contamination/remediation under tropical conditions that will be addressed in lectures/problem solving in the last part of the course.

Course goals
The overall goal of the course is to learn course participants main principles and the most important methods for management of contaminated soils with emphasis on how to clean and/or stabilize soils that are more or less contaminated by heavy metals, hydrocarbons (oil, PAH etc.) and/or other toxic compounds originating from various anthropogenic sources in different parts of the Nordic countries as well as other parts of the world.

After completing the course, the students are expected to have acquired the following knowledge, skills and competences:

- *Knowledge:*
    - Understand the importance of soil contamination in relation to human health and ecosystem functioning.
    - Describe the behavior of different heavy metals and organic pollutants in various soil types.
    - Outline importance and extent of soil pollution nationally and internationally.
    - Explain differences between remediation of soils contaminated by heavy metals and organic pollutants.
    - Explain potentials and limitations of various soil-cleaning methods both in-situ and ex-situ.
    - Understand influence of climate on remediation of contaminated soils.
- *Skills:*
    - Suggest proper method(s) for remediation of a heavy metal-polluted soil depending on soil type and degree and kind of pollution.

- Assess various methods for remediation of various soils contaminated by different organics under different climatic conditions.
- Apply knowledge about remediation of polluted soils in general to manage specific pollutions.
- Evaluate guidelines proposed by various bodies (authorities, consultants etc.) for remediation of specific kinds of pollution.

- *Competences:*
  - Define/describe terms such as ‘soil and water quality’, ‘soil washing’, soil extraction’, ´phytoremediation' and ‘hyperaccumulators'.
  - Reflect on environmental and societal problems created by contaminated soils.
  - Cooperate in an international forum (group) about creation of an oral presentation about how to manage a specific remediation problem.

Course plan

The course will run full-time over three weeks starting in the beginning of August. The total workload has been estimated to 137 hours distributed between different activities as indicated in the time table.

Time table

Activity	Number of hours
Lectures	30
Class problem solving	15
Excursions	20
Preparation	72
Total	137

These activities will be distributed over the three weeks as shown by the course schedule.

Schedule

Activity	1. week					2. week					3. week				
Preparation (course material reading)	X	X	X	X	x	X	X	x	x	x	x	x	x		
Thematic problem solving/submission				x	X				x	X			x	x	X
Lectures								x	x	X	x	X	X	x	
Class problem solving								x	x	x	x	x	x	x	
Excursion (≈6 h each)								X			X			X	
Course evaluation													x		x

X: Main activity; x: Minor activity

Well before course start, a detailed course plan showing each day’s subject(s) will be worked out and uploaded on KU’s study administration system, ABSALON. This plan will day by day describe activity, subject(s), preparation requirements (course material reading) and responsible teacher(s). During the first course period with distant learning, daily 2-h internet discussions will be arranged. For the last period at KU-LIFE, where teaching starts at 8 am and runs to 5 pm with 1-h break at noon, each 2-h teaching period will be described in details showing activity (lecture, problem solving, excursion), subject, preparation and responsible teacher(s). PowerPoint presentations to each lecture will be made available for the students on ABSALON no later than the day before the classroom presentation.

Course materials

Borggaard, O.K. 2010. Remediation of Heavy Metal Polluted Soils. To be prepared.
Handout notes/uploads of mainly review papers/book excerpts/reports/cases on factors and processes affecting soil contamination and on state-of-the-art methods that can be used to remediate soils contaminated by heavy metals and/or organic pollutants under different climatic and soil conditions. The course materials will be uploaded on ABSALON, and hence be available for course participants well before the course starts.

Course evaluation
The course will be evaluated through the normal 2-step procedure used at KU-LIFE. The first step is an evaluation by the students answering/commenting general and course-specific questions/statements about overall impression/output of the course, various course activities (lectures, problem solving, excursions, reports etc.), teacher performance, course material etc. This evaluation is done on ABSALON and will be completed in the last part of the course (cf. course schedule). Based on the evaluation by the students together with the teachers' perception of the course performance, the course responsible will made a draft evaluation report focusing on strengths and weaknesses of the course and with suggestions for improvements, which will be discussed with the students on the last course day. The outcome of this discussion will be addressed in the final evaluation report that will be worked out by the course responsible.
Both the students' evaluation and the final evaluation report will be submitted to all teachers and the study board at the Department for further consideration as well as to NOVA.