TRAINING LESSON 3 - Part 2 (Agrifood sector)

Title	○ **Pollutant fertilizer and eco-friendly alternatives – flipped classroom microlearning lesson + project-based additional homework**
Part of the training course referred to in this lesson	○ □ Part 1 General information about sustainability and CE Part 2 Specific Information about: □ Wood sector □ Plastic sector X Agrifood sector
EQF level	Level 2 or Level 3, in case of doing the optional tasks.
Where the lesson was tested	//
General Learning objective(s) according to the Bloom Taxonomy https://cft.vanderbilt.edu/guides-sub-pages/blooms-taxonomy/	X **Create** Produce new or original work (design, assemble, construct, investigate, formulate) X **Evaluate** Justify a stand or decision (appraise, argue, defend, critique, select, support) X **Analyze** Draw connections among ideas (differentiate, organize, relate, compare, distinguish, test, experiment) □ **Apply** Use information in new situations (execute, implement, solve, use, demonstrate, operate) X **Understand** Explain ideas or concepts (classify, discuss, describe, identify, locate, translate) X **Remember** Recall facts and basic concepts (define, duplicate, list, memorize, repeat)
Specific learning objective(s)	• Understand and analyze how intensive agriculture and the use of different fertilizers affect the quality of soils, underground waters and produce. • Remember, understand, analyze and evaluate how different microelements, used for fertilizing, affect human health and defend a

	selection of fertilizing options, which are less harmful, differentiating between them based on analysis of pros and cons. ● Understand what alternatives to harmful fertilization exist and be able to create their own presentations and reports on the topic.
Cognitive, socioemotional and behavioural outcomes based on https://www.unesco.de/sites/default/files/2018-08/unesco_education_for_sustainable_development_goals.pdf	**SDG 2 | Zero Hunger** Cognitive learning objectives: The learner understands the need for sustainable agriculture to combat hunger and malnutrition worldwide and knows about other strategies to combat hunger, malnutrition and poor diets, involving sustainable agriculture that does not pollute the environment and put human and environmental health in danger. Socio-emotional learning objectives: The learner is able to communicate on the issues and connections between combating hunger and promoting sustainable agriculture and improved nutrition. Behavioural learning objectives: The learner is able to change their production and consumption practices in order to contribute to the combat against hunger and the promotion of sustainable agriculture. **SDG 4 | Quality Education** Cognitive learning objectives: The learner understands the important role of education and lifelong learning opportunities for all (formal, non-formal and informal learning) as main drivers of sustainable development, for improving people's lives and in achieving the SDGs. Socio-emotional learning objectives: The learner is able to recognize the importance of their own skills for improving their life, in particular for employment and entrepreneurship. Behavioural learning objectives: The learner is able to use all opportunities for their own education throughout their life, and to apply the acquired knowledge in everyday situations to promote sustainable development. **SDG 6 | Clean Water and Sanitation** Cognitive learning objectives: The learner understands water as a fundamental condition of life itself, the importance of water quality and quantity, and the causes, effects and consequences of water pollution. Socio-emotional learning objectives: The learner is able to communicate about water pollution via questionable fertilization practices and to create visibility about success stories.

	Behavioural learning objectives: The learner is able to plan, implement, evaluate and replicate activities that contribute to increasing water quality and safety. **SDG 15 | Life on Land** Cognitive learning objectives: The learner understands the slow regeneration of soil and the multiple threats that are destroying and removing it much faster than it can replenish itself, such as poor farming. Socio-emotional learning objectives: The learner is able to create a vision of a life in harmony with nature via sustainable agricultural practices. Behavioural learning objectives: The learner is able to highlight the importance of soil as our growing material for all food and the importance of remediating our soils.
Green skill(s) addressed	X Creative problem-solving X Forward-thinking X Monitoring skills X Analytical skills ☐ Lean production ☐ Maintenance and repair skills X Pollution prevention ☐ Eco-design Management skills X Impact quantification X Life-cycle management X Science skills X Waste management X Environmental auditing X Ecosystem management ☐ Other___________________
Duration	20 minutes
Structure and content of the lesson	**INTRO** Soil is the space where nutrients transform into structures, which can be absorbed by plants, which allows for biomass to create and store carbon. Soil is where our future drinking water begins its purifying trip to underground waters. Excessive nutrient inputs lead to reduced plant species richness in a broad range of European ecosystems, damages the subterranean biomes, which are responsible for the natural replenishment of soil nutrients, pollute underground waters and ultimately the foods we consume. Soil is considered polluted when the pollutants negatively affect human health or the environment. Plants need nutrients in order to grow and yield fruit and intensive agriculture depletes these nutrients faster than nature can restore them. Fertilizers are

	used for introducing additional nutrients; however, plants are frequently unable to intake the entire amounts and the surplus, which is initially in the soil, sooner or later enters our water basins. Chemicals from long term pesticide use are discovered in soil samples all over Europe. More than 80% contain at least one type of residual pesticide substance and 58% contain two or more types. There is a set legal framework in Europe in regards to this, yet considering that the commitments to the majority of the relevant acts are not binding to the Member states, the processes of soil decontamination, restoration of degraded soils and prevention of further degradation as well as the increase of soil organic matter are not affirmed and the set deadlines for the targets remain wishful thinking (European Environment Agency, 2019) As far as the types of soil contamination are concerned, these can be diffuse and widespread or intense and localized (contaminated sites). Among the contaminants are heavy metals, persistent organic pollutants, residues of plant protection products, etc. Diffuse contamination via mass atmospheric deposition is decreasing. According to statistics provided by the Swiss Federal Office for the Environment in 2017, since 1990 lead contamination has shrunk by 87% and mercury contamination by 40%. However, metals, such as cadmium and copper, are still accumulating in arable soils. Before we discuss cadmium and copper, let's first look into nitrogen. **TOPIC 1 - NITROGEN** It is estimated that for approximately 65-75 % of the EU27 agricultural soils, **nitrogen** inputs through industrial fertilizers[1], manure, biosolids and nitrogen-fixing crops exceed critical values, beyond which eutrophication[2] is observed. While we do need nitrogen from fertilizers in our agricultural soils, we certainly do not need the released additional nitrogen in the atmosphere (in the shape of greenhouse gases) or in the waterways. Considering that only 50% of the added nitrogen, beyond the naturally fixed one, is consumed by the growing plants, while the rest is further processed by microorganisms producing the greenhouse gases or leaks into underground water. It has been estimated that about a 40 % reduction in nitrogen inputs would be needed on average across

[1] Fertilizers can be divided into three groups:
Mineral fertilizers (phosphorus and potash) are mined from the environment and crushed or chemically treated before being applied.
Organic fertilizers (manure and compost) are made from animal faeces, and plant or animal decomposed matter.
Industrial fertilizers (ammonium phosphate, urea, ammonium nitrate) are produced industrially by humans through chemical reactions.

[2] "Nutrient-induced increase in phytoplankton productivity". This rapid development of algae on the surface leads to a change in the light conditions for bottom algae, which die, forming toxic substances. The reduced amount of oxygen in the water is the reason for the death of both algae and fish and other aquatic inhabitants. The water quality itself is also deteriorating.

	Europe, for the purpose of limiting the negative effects. The solutions for this reduction that scientists are currently working on, are called improving the nitrogen use efficiency of agricultural environments. Here are a few examples of ongoing fertilizer research: -Microbiologists and soil scientists are trying to improve the conditions required for nitrogen-fixing[3] bacteria to grow more intensely. -Chemists on the other hand are working on designing fertilizers that are more stable when inserted in soils, i.e., less likely to be broken down by microorganisms. Just like some carbs that release energy slowly, these fertilizers continue releasing little bits of nutrients over a prolonged period of time, making sure that nutrients are available throughout the lifetime of the crops via a reduced amount of fertilizer. This would ultimately decrease the nitrogen that is lost in the air or water. -Plant biologists are using genetics in order to engineer crops that would require less nitrogen from fertilizers. The idea being that these crops would be able to obtain their own nitrogen from nitrogen gas, working together with the specialized microorganisms that are fixing nitrogen in the soil. -Turning to the technological domain, computer scientists are joining forces with soil scientists in order to design smart fertilization systems, which can monitor soil and air conditions and can add small amounts of fertilizer only when necessary. This would minimize the amount of fertilizer, which is introduced into the soil and would make sure that the fertilizer additions go to the crops that need them, thus decreasing the amount of nitrogen lost. **TOPIC 2 - CADMIUM** **Cadmium** accumulates in 45% of agricultural soils, mainly in southern Europe. It is mainly originating from mineral phosphorus fertilizers as it is present in the phosphate rock. In 21% of arable soils, the cadmium concentration in the topsoil layer exceeds the limit for groundwater, which is 1.0 mg/m3. In addition to transferring to water, cadmium poses another risk, especially under conditions that increase its solubility, i.e., enable it to transition into the plants themselves and from there into foods or stock feed. It is with utmost care that farmers need to monitor the administering of phosphorus fertilizers, trying to replace them with potassium and nitrogen fertilizers. Considering that cadmium competes with zinc and other elements in the soil for uptake by plants, the use of zinc fertilizers can also reduce cadmium accumulation by crops (Roberts, 2014). Additionally, saline soils as well as soils, which are irrigated with water that is

[3] Nitrogen-fixation is the process of converting nitrogen gas into nitrogen containing compounds. Nitrogen fixation can occur naturally through lightning strikes, be performed by specialized microorganisms, or be accomplished industrially.

high in chloride, also increase the solubility of cadmium. Therefore, in addition to monitoring fertilizers, irrigation water chloride levels should also be checked in order for cadmium uptake in crops and foods to be minimized.

Optional task: Assign to a group of students to review https://www.ncbi.nlm.nih.gov/pmc/articles/PMC7027482/ and/or other similar sources and develop a report on the adverse effects of cadmium accumulation in the human body.

TOPIC 3 - COPPER

While **copper** is an essential micronutrient, excess levels in soils are a source of concern. Copper has mainly been used for protection against fungi vineyards and orchards.

Results from the Land Use and Coverage Area Frame Survey (LUCAS) soil sampling 2009-2012 show increased copper levels in the soils in olive and wine-producing regions of the Mediterranean (Ballabio et al., 2018). Copper, which together with zinc is added to stock feed, is introduced into the environment through animal manure spreading.

There are three categories of possible remediation technologies for soil decontamination - physical, chemical and biological. Physical methods are laborious and costly but can be applied to highly contaminated sites; chemical methods have high efficiency and effectively remove copper; bioremediation methods including phytoremediation and microbial remediation are appropriate for large areas of soil contaminated by low concentrations of copper. The bioremediation method of microorganism assisted phytoextraction, where plants and bacteria are used, is the most promising solution for decontamination. As vineyards represent moderately polluted sites this technique has great potential there.

Optional task: Assign to a group of students to study https://www.researchgate.net/publication/328927651_Remediation_Technology_for_Copper_Contaminated_Soil_A_Review and develop a report on the three methods for remediation of copper polluted sites.

Among the possible copper alternatives can be mentioned D-tagatose, which is a natural sugar with a molecular formula identical to that of glucose and its structure is the mirror image of that of fructose. It is found in the exudate of a tropical tree, Sterculia setigera, and in certain lichen species (Rocella spp.). It can also be found in heat-treated dairy products, as lactose is also transformed into D-tagatose in small amounts when exposed to heat. (Bär, 2004). Some sugar compounds that rarely occur in nature or only occur in small amounts, such as D-tagatose induce systemic acquired resistance in certain plants, which results in increased resistance against many types of pathogens[4].

[4] https://www.biokutatas.hu/en/page/show/with-or-without-copper

TOPIC 4 - PESTICIDE RESIDUES

In addition to the above listed, there is also increasing concern about the accumulation of **pesticide residues** and their metabolites in soils (e.g. glyphosate and aminomethylphosphonic acid), and their potential release mechanisms (Silva et al., 2018). In the pilot study with LUCAS soil samples, over 80% of soils, which were tested, contained pesticide residues, with 58% of samples containing mixtures of two or more residues in a total of 166 different pesticide combinations (Silva et al., 2019). These results indicate the accumulative effects of pollutants, and that mixtures of pesticide residues in soils are the rule rather than the exception.

There are numerous possibilities for replacement of hazardous pesticides with safer alternatives. Examples of risk reducing approaches include: Integrated Pest Management, Conservation agriculture, Organic agriculture, Agroecology, Biological pesticides, Biological pest control, PEAT & Plantix, as listed on the website of the Rotterdam convention: http://www.pic.int/Implementation/Pesticides/Alternativestohazardouspesticides/tabid/8078/language/en-US/Default.aspx

Optional task: assign a group of students to study some of the approaches, listed on the website of the Rotterdam convention and to develop a report and presentation to be shared with their fellow students.

CONCLUSION

As conclusion, it can be mentioned that contamination of soils is widespread, indicating that the filtering capacity of soils has been abused and exceeded. We are also already facing the need to monitor and investigate the effects of such emerging contaminants as microplastics, endocrine disruptors, antibiotics and flame retardants.

Biologically mediated decomposition of organic material is the fundamental process for building the soil carbon stock, which, together with clay minerals, are important for nutrient retention and cycling. In all regions across Europe soil organisms richness (earthworms, springtails, mites, etc.) has been negatively affected by increased intensity of land use (Tsiafouli et al., 2015). Healthy soils contain active microbial (bacteria and fungi) and animal (micro to macro fauna) communities (Orgiazzi et al., 2016), of which bacteria and fungi are mainly responsible for nutrient cycling, essential for plant growth.

References

Ballabio, C., et al., 2018, 'Copper distribution in European topsoils: an assessment based on LUCAS soil survey', Science of the Total Environment 636, pp. 282-298 (DOI: 10.1016/j.scitotenv.2018.04.268).

Bär, A. (2004). D-tagatose, dossier prepared and submitted by Service.

	Bioresco on behald of Arla Food European Environment Agency. (2019). *The European environment — state and outlook 2020: Knowledge for transition to a sustainable Europe.* Luxembourg: Publications Office of the European Union, 2019. ISBN 978-92-9480-090-9. doi: 10.2800/96749 K.A. Mackie, T. Müller, E. Kandeler. (2012). *Remediation of copper in ineyards – A mini review.* Environmental Pollution, Volume 167, 2012, Pages 16-26, ISSN 0269-7491, https://doi.org/10.1016/j.envpol.2012.03.023 Orgiazzi, A., et al., 2016, Global soil biodiversity atlas, Publications Office of the European Union, Luxembourg. Roberts, T. (2014). Cadmium and phosphorous fertilizers: The issues and the science. Procedia Engineering, 83, 52–59. 10.1016/j.proeng.2014.09.012 Silva, V., et al., 2018, 'Distribution of glyphosate and aminomethylphosphonic acid (AMPA) in agricultural topsoils of the European Union', Science of the Total Environment 621, pp. 1352-1359 (DOI: 0.1016/j.scitotenv.2017.10.093). Silva, V., et al., 2019, 'Pesticide residues in European agricultural soils – a hidden reality unfolded', Science of the Total Environment 653, pp. 1532-1545 (DOI: https://doi.org/10.1016/j.scitotenv.2018.10.441). Tsiafouli, M. A., et al., 2015, 'Intensive agriculture reduces soil biodiversity across Europe', Global Change Biology 21(2), pp. 973-985 (DOI: 10.1111/gcb.12752).
Interactive questions for R3	Q1: Soil is considered polluted when both human health and the health of the environment are affected: True **False** Q2: The types of soil contamination are: **diffuse and widespread** dispersed and widespread intense and polarized **intense and localized (contaminated sites)** Q3: Nitrogen-fixation, which is the process of converting nitrogen gas into nitrogen containing compounds, can occur naturally through **lightning strikes**, be performed by specialized **microorganisms**, or be accomplished **industrially**. (fill in the blanks)
Keywords	Cadmium, Copper, Contamination, Decontamination, Eutrophication, Food safety through prevention, Greenhouse Gases, Nitrogen, Nitrogen Fixation, Mitigation, Pesticides, Risk reduction

Questions for reflection	1. Have you come across cases of proven agricultural area contaminations due fertilization? (investigate together with the students the case of China where the high input and low efficiency of fertilizers and pesticides have contributed substantially to the emissions of greenhouse gases such as CH4 and N2O, and the entry of pollutants into water bodies and soils, such as nitrogen and phosphorus, pesticide, and heavy metals, which would finally be transferred and accumulated in food. https://www.frontiersin.org/articles/10.3389/fnut.2021.703832/full) 2. Have you read about cases of water poisoning due to unsustainable agricultural practices? (research together with the students the case of Racoon river in Iowa, the USA: https://www.ewg.org/research/case-study-iowa-cities-struggle-keep-farm-pollution-out-tap-water) 3. What soil remediation methods are you aware of after this lesson? What about bioremediation? Study and discuss together "Bioremediation Techniques for Soil Pollution": https://www.intechopen.com/chapters/78227
Additional resources	EEA Publications - https://www.eea.europa.eu/publications/ IPCHEM - the Information Platform for Chemical Monitoring - https://ipchem.jrc.ec.europa.eu
Icons & related info for the hints of the PowerPoint presentation	This hint is used to indicate that there's a link to other websites with additional information. This is used within the PPT to indicate that something important is written/ to invite the reader to pay attention to essential information. This hint indicates a question/task for reflection.
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