Comprehensive assessment of fruits and vegetables human health effects in a LCA context

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ABSTRACT BOOK

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outdoor sediment-spiked microcosm experiment and those of 28-d sediment-spiked single-species toxicity tests with *Chironomus riparius*, *Hyalella azteca* and *Lumbriculus variegatus*. Twelve weeks after the construction of the microcosms mean measured exposure concentrations in the sediment were on average 87.7% measured initially. Treatment-related effects of sediment-spiked lufenuron in the microcosm experiment were observed for populations of insects and macrocrustaceans (lowest NOEC for benthic insects 0.8 µg a.s./g OC and for benthic crustaceans 8.5 µg a.s./g OC). Treatment-related increases in abundance (indirect effects) were observed for benthic oligochaete worms (lowest NOEC of 0.8 µg a.s./g OC). The 28-d sediment-spiked laboratory toxicity tests resulted in EC_{10} values of 0.49 µg a.s./g OC for *C. riparius*, 1.20 µg a.s./g OC for *H. azteca* and 211 µg a.s./g OC for *L. variegatus*. These data also explain why oligochaete worms did not suffer pronounced toxic effects in the microcosm experiment, but could increase in abundance due to the decline of sensitive benthic arthropod populations (release of competition). The chronic laboratory toxicity data mentioned above illustrate that the tier-1 effect assessment approach proposed by EFSA for benthic organisms and sediment-bound insecticides, using the lowest chronic EC_{10} value for the combination *C. riparius* and *H. azteca* and an assessment factor of 10, is protective for the insecticide lufenuron and the responses observed in the sediment-spiked microcosm test.

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Applying the MDD concept to terrestrial NTA studies

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Natural terrestrial ecosystems such as meadows adjacent to cropped fields may be exposed to spray drift. The arthropod fauna of such ecosystems is generally abundant and species rich and comprises a broad array of eco(toxico)logical profiles. There are no models or model systems sufficiently fit to adequately predict the potential effect of exposure on the functioning of these ecosystems. For this reason experimental tests are performed, generally in natural ecosystems without prior manipulation. Because the arthropod fauna in such systems varies between locations and years there is a need to evaluate whether a selected site is appropriate for the purpose of the experiment, i.e. to derive regulatory acceptable exposure levels. This can only be done a posteriori. We apply the MDD concept derived by Brock et al. (2015)[1] for aquatic micro-/mesocosm studies to natural (i.e. unbounded) terrestrial off field systems as described in DeJong et al.[2]. Typically these experimental systems follow a replicated (n=4) plot design, with 30x30 m plots and multiple sampling methods over a period of 8 weeks following a single application event. A large number of arthropod taxa (800-1000) is assessed and typically at least 80-100 are sufficiently abundant for statistical hypothesis testing. As a consequence of inherent parametric constraints we use non-parametric tests for these analyses. Our primary objective is to test whether the criteria in the aquatic scheme can be applied to derive regulatory acceptable exposure levels for terrestrial systems as well. We use the decision scheme in Brock et al. (2015) to data obtained in a large number of off-field studies. MDD's were calculated using the technique provided by Van der Hoeven (2008)[3]. Potentially sensitive taxa were defined using empirical criteria, in particular whether a specific or related taxon was consistently affected by the reference treatment in different studies. Ecologically vulnerable taxa were defined similarly as taxa consistently affected by the reference item for four or more weeks in different studies. [1] T.C.M. Brock; M. Hammers-Wirtz; U. Hommen;T. G. Preuss; H-T. Ratte; I. Roessink; T. Strauss; P.J. Van den Brink. Environ Sci Pollut Res (2015) 22:1160–1174. [2] F.M.W. de Jong; F.M. Bakker; K.Brown; C.J.T.J. Jilesen; C.J.A.M. Posthuma-Doodeman; C.E. Smit; J.J.M. van der Steen; G.M.A. van Eekelen. 2010 ISBN/EAN: 978-90-6960-245-5 [3] Van der Hoeven, N. 2008. Ecotoxicol.Environ.Saf. 70:61-66

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Development of suitable experimental designs for semi-field trials with solitary bees

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The publication of the proposed EFSA risk assessment of plant protection products for pollinators led to an increasing demand for experiments with non-*Apis* pollinators. However, no official guideline for the standardized semi-field trials exists so far. To overcome this lack of guidance, a semi field study was performed to continue our research and increase the knowledge about suitable test designs and the handling of the test organisms. The aim of this study was to implement a test system for trials under semi-field conditions with solitary wild bees. In the study the potential effects of exposure of bees and their brood to test item treated and untreated plants and the statistical evidence of validity were the focal points. During the exposure and after end of the exposure all relevant parameters were recorded. The test design is in accordance with a proposal from the ICPPR non- *Apis* working group. The semi-field study with the red mason bee *Osmia bicornis* (Hymenoptera, Megachilidae) was conducted in winter oilseed rape with 6 replicate tunnels per treatment group and contained a water treated control as well as two reference treatments applied with 100 g a.i./ha and 350 g a.i./ha dimethoate. The following end points were observed in the study: nest occupation by female individuals, flight activity, reproduction capacity by means of produced cells and cocoons and brood termination rate. Hatching success was also recorded to assess the viability of the used test specimens. The first results show clearly the possibility to perform semi-field studies with the red mason bee *Osmia bicornis* in winter oilseed rape. Dimethoate can be used as a toxic reference to show acute effects on adult wild bees. The endpoints chosen were useful for a study design and the variability was low with regard to the observed effects. The two rates of dimethoate tested showed already the maximum effect so that dimethoate can be used as a toxic reference in semi-field studies at the lower rate. Furthermore the statistical analysis showed that the test design is valid and repeatable.

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Experimental design for semi-field trials to test brood affecting plant protection products with solitary bees

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The newly proposed EFSA risk assessment of plant protection products for pollinators includes for the first time not only honey bees as test organisms but also non-Apis pollinators. However, there is no official guideline for standardized semi-field trials. To support a tiered risk assessment a semi-field study design was developed and performed in 2015 based on available publications and advices from an ICPPR workshop. The results of these studies make it possible to improve future designs and recommendations for the handling of the test organism can be given. The objective of this study was to develop a semi-field test design for plant protection products affecting brood of solitary wild bees. In the study the potential effects of exposure of adult bees and their brood to an insect growth regulator were examined. After the end of exposure the development of the progeny was followed until the following spring and the reproduction success was evaluated as an endpoint. The semi-field brood trial with the red mason bee *Osmia bicornis* (Hymenoptera, Megachilidae) was conducted in a *Phacelia* crop. The test design included a water treated control and two treatment groups. Each treatment group was replicated with 4 tunnels. The exposure period started at the beginning of July 2015. The treatment applied was fenoxycarb, an insect growth regulator also used as a reference substance in honey bee brood studies. Two rates were tested with150 g a.i./ha (T1) and 350 g a.i./ha (T2). The following endpoints were observed in the study: to evaluate sub-lethal effects on adult bees, the nest occupation of females and the flight activity was documented. I order to evaluate brood effects, the cell production, the cocoon production and the brood termination rate were assessed. To ensure equal starting conditions in all treatment groups the hatching success was recorded. The first results show, that it is possible to perform a semi-field brood study with the red mason bee *Osmia bicornis* in *Phacelia*. The bees can be stored until June and hatched specimens are still viable and fertile. Fenoxycarb can be used to introduce brood termination in eggs and larvae of red mason bees. The endpoints chosen are useful to evaluate effects on reproductive success and the variability between replicates was low. The lower rate of fenoxycarb showed already the maximum effect so that fenoxycarb can be used as a toxic reference in semi-field studies.

Methodological challenges for LCA of agricultural supply chains producing food, fibre and bioenergy

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Comprehensive assessment of fruits and vegetables human health effects in a LCA context

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Purpose: Nutritional effects from the 'use stage' of food items life cycle can have a substantial effect on human health; yet, they are often not considered in life cycle assessment (LCA). In our study we explore the case of increased fruit and vegetable consumption, a healthy dietary option – that could result in higher exposures to a wide variety of pesticides – and investigate the trade-offs between associated environmental and nutritional health effects. *Methods:* We employ the Combined Nutritional and Environmental Life Cycle Assessment (CONE-LCA) framework that evaluates and compares in parallel the environmental and nutritional effects of foods expressed in Disability Adjusted Life Years (DALYs). For the environmental health assessment we consider impact categories such as global warming and particulate matter (PM) as well as chemical exposure due to pesticide residues. Global warming and PM are assessed following a traditional LCA approach. For the pesticide residue exposure, we use publically available health impact scores derived from toxicological studies of numerous pesticide active ingredients. For the nutritional assessment we focus on the various health outcomes considered in the global burden of disease that are based on epidemiological studies. *Results and discussion:* Adding one serving of fruits or

vegetables to the current average diet in Europe may lead to substantial nutritional health benefits. These nutritional benefits are slightly increased when we consider substitution scenarios in which the substituted food items are associated with negative health effects, such as red meat and trans-fat. Overall environmental health impacts associated with this addition are substantially smaller compared to nutritional benefits in each scenario, even when considering an uncertainty factor of 400 for the impacts of pesticide residues. *Conclusion:* The present study illustrates the importance of considering nutritional effects of food items in LCA. Our preliminary results suggest that nutritional health effects of food items can be substantial and comparable to environmental impacts, especially for nutritional foods such as fruits and vegetables. This approach could be used for making recommendations about sustainable diets and food choices.

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Pesticides' impacts of bananas from different regions

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Most bananas sold in Europe nowadays have some sort of sustainability label. Consumers and supermarkets therefore may have the idea that the labelled bananas are produced in a sustainable way. Sustainability covers many social and environmental themes and several of these are addressed by the labels only to a certain extent. However, large amounts of pesticides are still used in conventional banana production, resulting in potential human health and ecosystem impacts. Using no xenobiotic pesticides at all as is the case for organic bananas is not an option for the large scale, because it needs very specific climatic and logistic conditions. Different climatic, soil conditions and production practices between farms result in large differences in the pesticide impact of bananas. In this study, the toxicity-related impacts of pesticides applied in banana production were calculated with the consensus model USEtox version 2.0 for three case studies: an organic farm in Peru, smallholder farms in Ecuador, and a conventional plantation in Panama. The resulting toxicity-related pesticide footprints show that the use of large quantities of myclobutanyl, chlorpyrifos and mancozeb in Panama case have the highest contribution to the human health impact profile. The use of azoxystrobin and mancozeb in this case shows the largest share on the impact profile for organisms in freshwater ecosystems. The footprint of the pesticides used in banana production from the Panama case is about 20 to 30 times larger than in the Ecuadorian case. In a sensitivity analysis, in each case, regionally specific landscape parameters were used to calculate specific factors for each of the pesticides used. This increased the score of the Panama case by about 300%, while the score of the Ecuador case did not change significantly. Default values for these parameters are provided by USEtox for several regions, among which for a region covering Central America and one covering Peru and southern Ecuador. Calculations with an alternative impact assessment model (USES-LCA) generally confirms the results with USEtox, but shows that the impact on terrestrial and marine ecosystems, which are not included in USEtox, can be significant.

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Towards a consensual method to assess climate change impacts from bio-based systems

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This study focused on climate change impact assessments of systems involving compartments of the biogenic carbon cycle, addressing the issue of assessing the actual impacts of biogenic carbon emissions and of variations in carbon stocks. A critical review was carried out on seven different characterisation models dealing with these environmental mechanisms, including five methods dealing with GreenHouse Gas (GHG) emissions - conventional Global Warming Potentials (GWP) from IPCC according to a carbon neutrality approach or to a full accounting approach, time-adjusted GWP, biogenic GWP and biogenic accounting factors - and two methods dealing with land occupation and/or transformation - ILCD / IPCC recommendation to account for carbon stock changes from land transformation and Müller-Wenk proposal adopted in the land use framework. These models were rated over eight criteria divided into four categories: completeness in terms of environmental mechanisms covered, scientific soundness, genericity, and easiness of use. Results showed that the currently recommended methods are conventional GWP according to a full accounting approach for the assessment of greenhouse gas emissions, and the ILCD / IPCC recommendation to account for carbon stock changes from land transformation. However, despite their good international acceptance, these methods fail to take into account the dynamic nature of the biogenic carbon cycle and new methods have then been developed for this purpose. These methods present many gaps but two were identified as promising characterisation models: time-adjusted GWP and Müller-Wenk proposal. Finally, a new method that benefits from the advantages of these two last methods is proposed. This method relies on the land use framework related to carbon sequestration potential with the time-adjusted GWP embedded to better reflect the dynamics and reversibility of the biogenic carbon cycle. It is compatible with full accounting approach for GHG emissions and temporary carbon storage valuation. It also remains sufficiently practicable.

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Which functional unit to assess environmental impacts of dairy system intensification?

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Intensification of milk production, defined as increased production per hectare (ha) of land, invariably leads to increased impacts per ha, but its impacts per kg of milk are less clear. The aim of this study was to assess a range of environmental impacts of contrasting dairy systems that represent a wide diversity of management practices and intensification levels. We used the concept of the Technological Management Route (TMR), i.e. a logical set of technical options designed by farmers, to compare seven systems representing the diversity of milk production systems in France and a range of intensification levels. Life Cycle Assessment was used to estimate impacts of these systems using two functional units (FU): t of milk and ha of total (on- and off-farm) land occupied. With the area-based FU, we are looking for low-impact land-use systems. From this perspective, the organic and highland systems were most promising. With the mass-based FU, we consider productivity and impacts. From this perspective, a maize-silage based system seemed most promising, as it ranked lowest or second-lowest for six out of seven impacts. Dairy system intensification had three effects: i) all impacts increased per ha of land occupied, ii) eutrophication and land competition decreased per t of milk produced, and iii) other impacts changed little per t of milk produced. In other words, depending on the FU, the perceived environmental impacts of dairy system intensification differed radically. A mass-based FU is by far the dominant FU, and, in studies that go beyond the farm gate, the only FU used. Thus, current LCA practice is largely blind to environmental impacts of dairy system intensification, as it tends to ignore the environmental impacts of intensification revealed by the area-based FU. This is a sobering observation with paradoxical consequences, as this “blind spot” of current LCA practice may well tend to bias decision making in favour of intensive systems, which have high impacts per ha of land occupied. LCA-based decision making might thus increase the prevalence of intensive systems, which could increase overall impacts of the agricultural sector. Reconciling environmental impacts and productivity is difficult. Using only a mass-based FU, does not provide a balanced view of the impacts of intensification and could mislead decision makers in identifying promising dairy systems. We recommend the use of both mass-based and area-based FUs in LCAs of agricultural goods.

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Environmental Impact of food consumption in EU

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In order to comprehensively assess the impact of food consumption at EU level, a detailed product based LCA from ‘cradle to grave’, has been conducted aiming at: i) identifying the most representative food and beverage products consumed in the EU-27 via a statistical analysis of food consumption, selecting 2010 as reference year, ii) evaluating, via an LCA, the life cycle environmental impact of the average food consumption of an EU-27 citizen in one year following the ILCD recommendations for impact assessment, iii) developing a strategy for using the BoP food as baseline scenario for testing ecoinnovation options for impact reduction. The methodology developed for assessing the impacts of food consumption in EU, based on a basket of food products, includes the following steps: 1) Quantitative and qualitative analysis of the structure of the EU consumption category of nutrition – during the years 2000-2010 – including international trade and selection of a basket of representative products for the consumption category of nutrition for the year 2010. 2) Collection and development of process-based LCIs for the selected representative products. 3) Calculation of the environmental impact results, based on the results of the previous steps. 4) Quantitative and qualitative analysis of the environmental impacts of the selected nutrition basket, with conclusions and recommendations for the future. The overall results indicate that in the majority of the impact categories the most burdening consumed foods are meat products and dairy products. The agricultural phase is the most impacting lifecycle stage of the basket food, due to the contribution of agronomic and zoo-technical activities. Food processing and logistics follow in importance, due to their energy intensity and the related emissions to atmosphere, occurring during the production of heat, steam and electricity and during transport. Regarding the end of life, human excretion and wastewater treatments are posing burdens related to euthrophying substances. The impact assessment results of this study could be used as a means to provide an index for monitoring and analysis, in order to evaluate the effect of possible improvements within the life cycle stages and the different supply chains. A further step of the analysis should be to develop scenarios of eco-innovation and behavioural changes to test their effect at the EU scale and to prioritize their implementation.

Persistent and mobile contaminants in the aquatic environment: how to identify, analyse and regulate a