Impact of heavy metals on human toxicity using LCA: a case study for Walloon corn

S. Gerbinet[1], F. Van Stappen[2], S. Belboom[1], E. Pezennec[3] and A. Léonard[1]

[1]Chemical Engineering – Products, environment and processes (PEPS) - University of Liège, Belgium, B6, allée de la chimie 3, 4000 Liège
[2]Walloon Agricultural Research Centre, Chée de Charleroi 234, 5030 Gembloux
[3]Knauf Insulation Sprl, Rue de Maestricht 95, 4600 Visé, Belgium

E-mail contact: Saicha.Gerbinet@uliege.be

1. Introduction

In this work, we want to emphasize the limitations that we observed when using databases, inventories and methodologies as black boxes. Sources of errors and misinterpretation are illustrated in the particular case of assessing the toxicity of heavy metals using the USEtox methodology [7] during the production of corn.

2. Case study: corn production in Wallonia

The studied system is the production of corn in Wallonia (South of Belgium), whose the primary data are taken from Van Stappen, Mathot [9]. The functional unit is 1 hectare of corn crop in Wallonia. The LCI data are based on actual agricultural practices recorded in farms' accounting data. The field emissions due to the application of inputs were assessed by emission models as recommended by Nemecek [4]. The system has been modelled in GaBi 7 [3] using GaBi datasets.

3. Results

3.1. Human toxicity, cancer effect: the case of chromium

The human toxicity, cancer effect impact of farming 1 hectare of corn in Wallonia is 3.59E-04 CTUh, mostly due to chromium emissions in freshwater and in soil from the organic and mineral fertilizers. All chromium emissions are classified in unspecified chromiumemissions due to the sole dosage of total chromium during the fertilizers analysis. However chromium is present as Cr (+III) or Cr (+VI) and, depending on its oxidation level, its toxicological impact is completely different. Indeed, there is no impact for Cr (+III) but a tremendous impact for Cr (+VI). In USEtox, the characterization factor for unspecified chromium is the average of both. Cr (+VI) is a powerful oxidant and therefore is very reactive. In the presence of organic components, Cr (+VI) will react quickly and will be reduced to Cr (+III). It is therefore realistic to suppose that all the chromium from organic fertilizers is Cr (+III). Moreover, in mineral fertilizers the chromium mostly comes from the rocks used in their production, such as dolomite or phosphate rock. As Chromium exists as Cr (+III) in the natural environment, the chromium in mineral fertilizers should also be Cr (+III) [1, 8]. The speciation of chromium in fertilizers has been studied and always shows a very small portion of Cr (VI), generally smaller than 2 % [2].

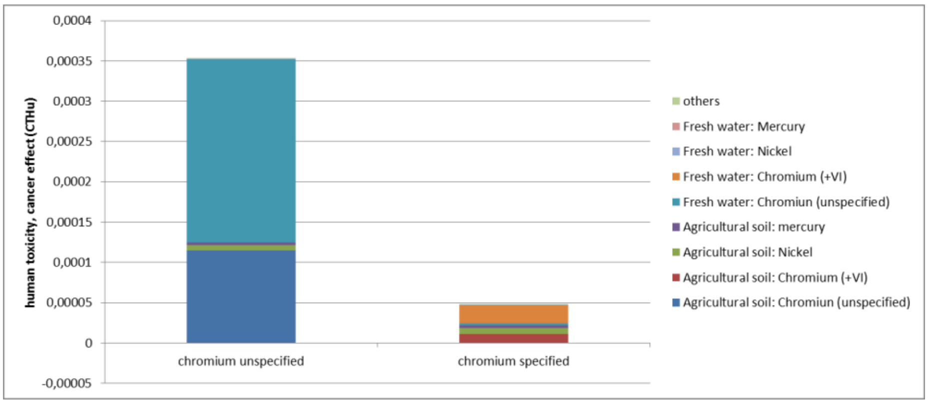

Figure 1 : Impact on human toxicity, cancer effects, of the farming of 1 hectare of corn in Wallonia. Influence of the speciation of chromium.

Therefore, a test is performed where 95 % of the chromium emissions from fertilizers is considered as Cr (+III) and the rest as Cr (+VI). With this change, the impact in the aforementioned category is divided by 7. In this case, the Cr (+VI) emissions to agricultural soil and to fresh water have still the largest contribution to the impact (62 %), as underlined in Figure 1. The other main contributors are other metals emissions to agricultural soil, mainly nickel (12 %) and mercury (10 %).

On the other hand, the emissions of pesticides in the soil contribute to less than 1 % of the total impact even if their total amount is larger than the total amount of metal emissions. This is because some of them have no characterization factors. Considering around 2.2 kg of pesticides (all included) applied by hectare, only 1.2 kg is characterized in USEtox. Most of them have only C.F. in human toxicity non-cancer effect. Finally, the C.F of the pesticide presented in this study is small compared to the C.F. of metals for emissions in agricultural soil. For example, atrazine is the pesticide from this study with the larger C.F. (1.3 10-6 CTUh/kg) which is smaller than the C.F of all the metals included in this category.

3.2. Human toxicity, non-cancer effect: the case of zinc

The human toxicity, non-cancer effects of farming 1 hectare of corn in Wallonia is 0.0231 CTUh. It is mostly related to zinc emissions in soil due to organic fertilizers, especially to pig manure and in a lesser extent to mineral fertilizers. Zinc is abundant and is an important trace element in the human body. Moreover, mammals are able to eliminate zinc, therefore they are able to maintain a constant level of zinc independently of the exposure level. This is not the case for the soil and the vegetables, where the zinc can be accumulated and interfere with the absorption of other metals. For human, only the exposure to high doses can have toxic effects because it interferes with the uptake of copper. On the other hand, some zinc compounds such as zinc chloride can be toxic [5, 6].

Therefore, this high contribution of zinc to non-cancerous toxicity for human is quite surprising. In USEtox, the characterization factors are calculated by multiplying the effects [cases/kg_{intake}] by the intake fraction [kgintake/kgemmitted]. The intake fraction is the fraction of the emission that is taken by the overall exposed population. The effect factor of zinc is small in comparison to other metals; however, its characterization factor for emissions in agricultural soil is high because its intake fraction is high. A test was made with the characterization factor of zinc equal to 0 in the USEtox model. In this case, the corn cropping obtains a human toxicity, non-cancer effect of 0.00179 CTUh, mostly related to lead and mercury emissions in the soil Figure 2). The same observation than before can be made for pesticides: their impact is smaller than 1 %.

4. Discussion and conclusions

This work underlines the uncertainties related to the characterization of human toxicity in LCA. The impact of some metals is especially high even if their measurements are not accurate (unspecified chromium human toxicity) or if their characterization factors are surprisingly high (zinc in human toxicity, non-cancer effect). Although the uncertainties about toxicity categories are well-known, this case study underlines the impact of the user hypotheses and shows that a detailed analysis of the results is essential. Future work will include contacting experts in the toxicology of metals to have a better understanding of the impact of zinc. A better evaluation of chromium speciation in fertilizers is also planned.

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