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Estimating soil emissions and toxicity impacts from the application of livestock manure: application to heavy metals at national scale

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1. Introduction

Aiming for a more efficient use of resources, the European Commission encourages the use of animal manure as a fertilizer providing nutrients and organic matter to improve crop productivity and soil fertility [1,2]. However livestock manure contains traces from pathogens, veterinary medicines and feed additives (e.g. antibiotics and heavy metals), which may cause damages to ecosystems and human health. To prevent large damages from happening, tools such as Environmental risk assessment (ERA) and life cycle assessment (LCA) are used to evaluate the environmental risks and impacts of the pollutant emissions resulting from manure application. Both methodologies first require an estimation of the emissions to soil as part of their respective stages of exposure assesment and life cycle inventory analysis.

To provide consistent support to high level policy-makers, e.g. supporting regulations on the use of such substances in livestock production, large-scale assessments are required. To date, the total emissions of harmful substances resulting from the application of manure at country level have however been rarely quantified. We therefore developed a framework to estimate these releases to soil in a systematic way. We applied it to emissions of 8 heavy metals (HMs) in 215 countries from 2000 to 2014 and analysed the resulting environmental toxicity-related impacts based on life cycle impact assessment.

2. Materials and methods

2.1. General framework

The release of a substance to the agricultural soil is directly related to the quantity of manure applied and the concentration of the substance in the manure. The latter varies between livestock, depending on the amount ingested, the fraction excreted and the manure management system (solid manure or liquid slurry). We propose a methodology to estimate the input quantity $Q(S)_{l,t,c,y}$ of a substance S to the agricultural soil resulting from the application of manure of type t (solid or liquid) from the livestock l in the country c in year y:

$$Q(S)_{l,t,c,y} = M_{l,c,y} \times P(t)_{l,c,y} \times C(S)_{l,t,c,y} \qquad \text{(Equation 1)}$$

Where $M_{l,c,y}$ is the amount of manure from the livestock l applied in country c in year y (in kg N-content); $P(t)_{l,c,y}$ is the proportion of manure of type t for the livestock l in country c in year y (in %); $C(S)_{l,t,c,y}$ is the content of substance S in manure of type t from the livestock l in country c in year y (in g/kg N-content).

2.2. Application to heavy metals and impact assessment

Quantities of manure applied, manure management systems were retrieved for each year and country from international databases and studies [3,4]. Manure concentrations of arsenic, cadmium, chromium, copper, mercury, nickel, lead and zinc were investigated through a literature review.

To quantify the impacts of the HMs released from the application of manure on human health and freshwater ecosystems, the life cycle impact assessment method USEtox was used [5,6]. Resulting impact scores were then normalized by the area of cultivated agricultural land by country, as retrieved from FAOSTAT [3].

3. Results and discussion

3.1. Literature review of heavy metal concentrations

The literature review led to the identification of the AROMIS database [7] and 16 papers. HM concentrations appear to be very sensitive to the living conditions of the livestock, the maturity of the compost, and the sampling and analytical methods, which differ between studies and countries [8].

HM contents measured in European countries showed no general increase or decrease over time. Developing countries turned out to show up to 100 times higher concentrations than the European geomean. Due to the lack of documentation in the retrieved studies and the diversity of measuring conditions, it was not possible to determine if the different concentrations are the effect of distinct living conditions or analytical methods. Any differentiation by country or year was thus deemed irrelevant, and European average contents by livestock were used as an approximation.

3.2. Inventory results

China, India, the United States of America, Brazil and Russia are the top 5 countries in the world with respect to the quantities of manure applied, for example accounting altogether for 48% of the global Ni emissions to soil. Releases in China or India may even be underestimated as actual HM concentrations are believed to be higher in such developing countries than modelled here. Time-wise, two general emission patterns could be observed. While HM releases have usually been increasing in developing countries since 2000, they remained rather stable or decreased in developed countries.

3.3. Toxicity impacts

Hg, Zn and Cu are the HMs contributing the most to the worldwide impact scores obtained respectively for impacts on human health (cancer effects and non-cancer effects) and on freshwater ecosystems. They should therefore be addressed in priority by regulations addressing use of HMs in manure or feedstuff. Normalising the toxicity impact scores by the area of agricultural land highlighted regions where the releases are the most intensive (Fig. 1). Europe and South-East Asia also showed intensive emissions and should be more deeply investigated to ensure more environmentally-sustainable manure management.

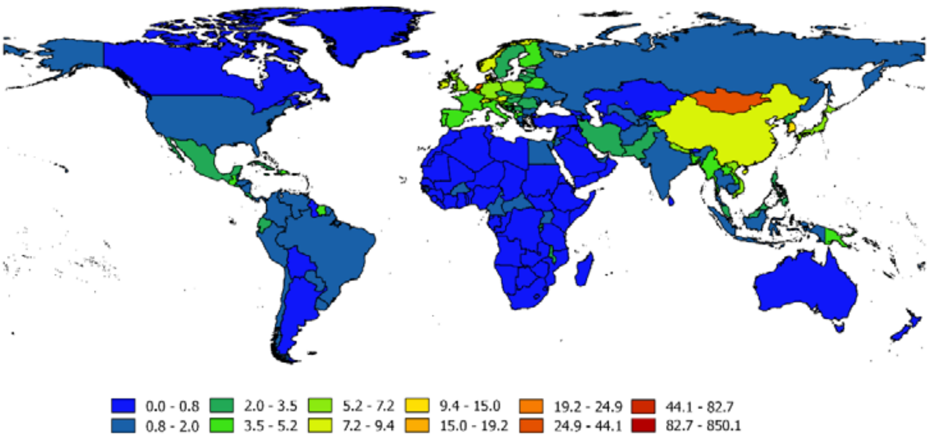

Figure 1: Impacts on human health normalised by the area of agricultural land in 2013 (in cases/1000ha)

4. Conclusions

The framework developed in this study helps screening the toxic emissions of heavy metals and associated impacts from the application of manure on agricultural soil. Used in LCA context, it allows identifying metals and regions that show the highest impact and support prioritsation in policy-making. In ERA context, it can be used as a preliminary step for exposure assessment to estimate released quantities and predicted environmental concentrations. Establishing international sampling and analytical methods for measuring the heavy metal content of manure is however critical to support policy in a scientifically consistent way.

5. References

[1] EC, 2012. The implementation of the Soil Thematic Strategy and ongoing activities. Brussels
[2] Hepperly P. et al., 2009. Compost, manure and synthetic fertilizer influences crop yields, soil properties, nitrate leaching and crop nutrient content. Compost Sci Util 17:117-126.
[3] FAO, 2016. FAOSTAT. http://faostat3.fao.org/home/E Accessed 2/11/16.
[4] Kuczyński T. et al., 2005. Emissions from European agriculture. Wageningen Academic Pub.
[5] Rosenbaum R.K. et al., 2008. USEtox - The UNEP-SETAC toxicity model: Recommended characterisation factors for human toxicity and freshwater ecotoxicity in life cycle impact assessment. Int J Life Cycle Assess 13:532-546.
[6] Hauschild M.Z. et al., 2008. Building a Model Based on Scientific Consensus for Life Cycle Impact Assessment of Chemicals: The Search for Harmony and Parsimony. Environ Sci Technol 42:7032-7037.
[7] KTBL, 2005. Welcome to AROMIS. http://daten.ktbl.de/aromis/welcome.do Accessed 13/05/2016.
[8] Amlinger F. et al., 2004. Heavy metals and organic compounds from wastes used as organic fertilisers. Study on behalf of the EC.