Environmental and energetic approaches of fertilising practices: comparison of four spreading practices with LCA tool

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Abstract: *This paper explores an environmental analysis, with Life Cycle Assessment (LCA), of four spreading scenarios (liquid sewage sludge, cattle manure, pig slurry and mineral fertilisers) in order to identify the main impacts during the fertilisation processes from an energetic and environmental point of view. CML (Centrum voor Milieuwetenschappen Leiden) and CED (Cumulative energy demand) methods were used for this purpose. This comparison between spreading scenarios points out the major problems which need to be solved. It guides the ecodesign of new spreading machines and guides future researches to identify farmers' best fertilising practices from an environmental and energetic point of view.*

Keywords: *Life Cycle Assessment, spreading practices, environmental impacts, GHG emissions*

Context

As fertilisers represent 19% of the energy consumption in a farm, an ADEME study recommends reducing nitrogen losses by improving fertilising decision tools. To define new environmental-oriented practices, it is necessary to evaluate their energetic and their environmental impacts. With this study, we try to allocate these impacts either to the material (fertilisers) or to the machine (spreaders) by using Life Cycle Assessment (LCA) tool. LCA evaluates energetic and environmental performances of goods, products or services throughout their life cycle (from "cradle to grave") based on the ISO 14040 standards (ISO, 2006). Our study focuses on the energetic and environmental impacts of four spreading practices (liquid sewage sludge, pig slurry, cattle manure and mineral fertiliser).

Goal and scope

System boundaries and functional unit

As defined in a previous study (Thirion, 2006), the system is limited to the fertiliser's application on the field. The functional unit permits to compare different systems for the same given service, in our case the fertilisation. To compare different spreading scenario, the functional unit is based on the amount of fertilisers needed to apply 170 kg of nitrogen per ha as mentionned in the Nitrate Directive. A reference flow is calculated for each scenario according to this functional unit, *i.e.* 20 tons of cattle manure, 23,6 m3 of pig slurry, 300 kg of ammonitrate and 100 kg of triple superphosphate and 41,67 tons of liquid sewage sludge.

Hypothesis, data and scenario description

Data used for scenarios definition, material, mineral fertilisers fabrication, fuel consumption and tyres abrasion come from literature (Nemecek, 2004; Thirion, 2006) as well as from the Ecoinvent database. Data for fertilisers spreading emissions come from literature (Brentrup, 2000; Ademe/Sogreah, 2007) and are related to spreaders distribution performances. Each scenario is based on realistic economic and technical fertilising practices investigated by the Cemagref's Pôle Epandage Environnement (Montoldre, France).

Energetic and environmental impacts of four spreading scenarios

Energetic impacts

The Cumulative Energy Demand (CED) method (Frischknecht R. et al., 2004) is used to evaluate the energetic impact of the four spreading scenarios (Table 1). From an energetic point of view, the mineral fertiliser spreading scenario has the most negative impact regarding the energy used – followed by the liquid sewage sludge, the cattle manure and the pig slurry spreading scenarios – due to the mineral fertilisers' fabrication.

Table 1. Cumulative energy demand of four fertilising practises scenarios

Impact category	Unit	Sewage sludge	Mineral fertilisers	Cattle Manure	Pig Slurry
Total	MJ-Eq	1 677	7 640	711	390
Non renewable, fossil	MJ-Eq	1 432	6 794	605	333
Non-renewable, nuclear	MJ-Eq	165	604	72	38
Renewable, biomass	MJ-Eq	26	113	10	6
Renewable, wind, solar...	MJ-Eq	2	15	1	0
Renewable, water	MJ-Eq	53	115	22	12

Environmental impacts

In 2001, the Institute of Environmental Sciences of Leiden University (CML) published a new “operational guide to the ISO standards” (Guinée et al., 2001) describing the procedure to be applied for conducting a LCA project according to the ISO standards with a "problem oriented approach".

Table 2 presents environmental impacts of the four spreading scenarios. For Global Warming (GWP100) impact, the worse scenario is still the mineral fertilisers spreading scenario – followed by the sewage sludge, cattle manure and pig slurry – due to the mineral fertilisers' fabrication. For two impact categories related to ecotoxicity (FWAE and TE), the sewage sludge scenario is worse than the three others due to the heavy metals content of the sewage sludge. For the acidification (AP) and eutrophication (EP) impact categories, the pig slurry spreading scenario is worse than the cattle manure or sewage sludge scenarios because of the high ammonia volatilisation and high nitrate leaching. For these five last impact categories, mineral fertilisers spreading scenario has the best results.

Table 2. Characterisation impacts of four fertilising practises scenarios with CML method

Impact category	Unit (eq)	Sewage sludge	Mineral Fertiliser	Cattle Manure	Pig Slurry
GWP100	kg CO_2	675	1 522	620	603
HT	kg 1,4-DB	1 172	454	543	290
FWAE	kg 1,4-DB	424	56	253	345
TE	kg 1,4-DB	207	8	77	39
AP	kg SO_2	44	6	9	61
EP	kg PO4---	11	8	12	20

Discussion and conclusion

The energetic analysis shows that the mineral fertilisers spreading scenario is worse than the three others due to the energy demand for ammonia synthesis. However, the substitution of mineral fertilisers by organic fertilisers leads to various harmful emissions. These emissions are partly due to a poor quality of the spreading distribution. Their calculation constitutes a basis for an ecodesign approach. It will also guide an assessment of farmers' fertilising practices from an environmental and energetic point of view. It seems important to use a method based on energy demand together with another multicriteria method in order to have an overview of all environmental impacts. This assessment may be enhanced if Crutzen hypothesis (Crutzen et al., 2007) is validated, as GWP100 calculated impact will then be widely altered by N_2O emissions reconsidering.

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