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Accounting GHG emissions from sludge treatment and disposal routes – methodological problems focused on sludge land spreading in agriculture

Reverdy Anne-Laure^{1*}, Pradel Marilys¹

(1) Irstea, UR TSCF, Domaine des Palaquins, 03150, MONTOLDRE, FR

*Corresponding author: anne-laure.reverdy@irstea.fr

Abstract

In France, more than 70% of sewage sludge is directly land spreading or composted before land spreading. Sludge application is responsible of greenhouse gases (GHG) emissions. In 2010 and 2011, Irstea produces a tool called ^GE_STABoues to quantify GHG emissions emitted during sludge treatment and disposal routes. This paper aims to present how this tool can be used to quantify GHG emissions of sludge land spreading of a 380 000 per captia equivalent wastewater treatment plant (WWTP) and to point out methodological aspects that could invert results of GHG emissions. Conclusions in GHG emissions results could vary depending on the system boundaries used, especially regarding additional fertilisation with mineral fertilisers and could be responsible for possible misunderstanding in conclusions of environmental assessment.

Introduction

During the last decades, European institution establishes regulations which aim at protecting the environment from the adverse effects of the collection, treatment and discharge of waste water (Directive 91/271/EEC of 21 May 1991 concerning urban waste water treatment) and at maintaining and improving the aquatic environment (Directive 2000/60/EC of 23 October 2000 establishing a framework for community action in the field of water policy). These regulations were transcribed in French laws leading to important constraints on the waste water treatment plants (WWTP).

The application of this European and French laws leads to an increase in sludge production (from 947 000 in 2003 to 1 100 000 dry matter tons in 2008) which is eliminated according four main disposal routes: land spreading (directly or after composting), incineration, incineration with household wastes and landfilling.

A recent study (Reverdy and Pradel, 2010) shows an increase in sludge land spreading from 60 to 70% with a significant evolution of composted sludge spreading.

In order to help stakeholders in their decision making, we developed a decision tool to assess the impact on global warming of different sludge treatment and disposal routes: ^GE_STABoues.

This paper aims to present a possible use of ^GE_STABoues tool in order to quantify greenhouse gases emissions for sludge land spreading that come from a 380 000 per captia equivalent WWTP and to identify the impact of system boundaries definition on greenhouse gases emission accounting results.

Material and methods

^GE_STABoues tool

The ^GE_STABoues tool allows the calculation of the environmental impact on global warming of sludge treatments and disposal routes. The method underlying this tool is explained in Reverdy and Pradel (2011). It is based on the “Bilan Carbone[®]” method (ADEME, 2009) and Life Cycle Assessment standards (ISO 14040 and ISO 14044).

In our method, three GHG are recorded: carbon dioxide (CO₂), methane (CH₄) and nitrous oxide (N₂O). As the quantification of these gases cannot be directly measured, we used data from literature or calculated them with adequate equations for each processes involved in the studied activities. The amount of each gas is then converted with an emission factor in CO₂ equivalent (CO₂eq) according to their Global Warming Potential (GWP) over 100 years: 1 for CO₂, 25 for CH₄ and 298 for N₂O.

C-CO₂ emissions can be either from fossil or biogenic origin. Biogenic C-CO₂ emissions are belonging to short carbon cycle. They are involved in photosynthesis or thermal or biological ways of oxidation so as the emitted biogenic C-CO₂ is rapidly incorporated in the carbon cycle. These biogenic emissions are not taken into account in national protocols as they are considered (by convention) as “carbon neutral” (GWP equal to zero). In ^GE_STABoues tool biogenic C-CO₂ is not accounted. As

fossil C-CO₂ emissions come from the hydrocarbon combustion, stored in the Earth surface from million years, they are belonging to the long carbon cycle. Releasing this fossil carbon by combustion increases the amount of C-CO₂ in the atmosphere and these emissions need to be accounted.

Three types of emissions are considered in ^GE₅TABoues tool: direct, indirect and avoided emissions. Direct emissions are emissions directly produced by the process or the studied activity (ex: CO₂ emissions due to fuel combustion during the activity). Indirect emissions are produced by processes needed by the activity but not directly generated by the activity (ex: CO₂ emissions during transport of goods). Avoided emissions are generated when products are not used and replaced by recyclable products (heat, electricity, fertilizer...).

The system boundaries are limited to the sludge treatment including all the possible disposal routes (Figure 1). Two types of analyses are done to assess GHG emissions: a detailed analysis for all the sludge treatment processes and disposal routes and a global analysis for the consumables, transport and infrastructure involved in the system. The GHG emissions are assessed for the total amount of sludge produced by a WWTP of x Per-Capita Equivalent (PCE).

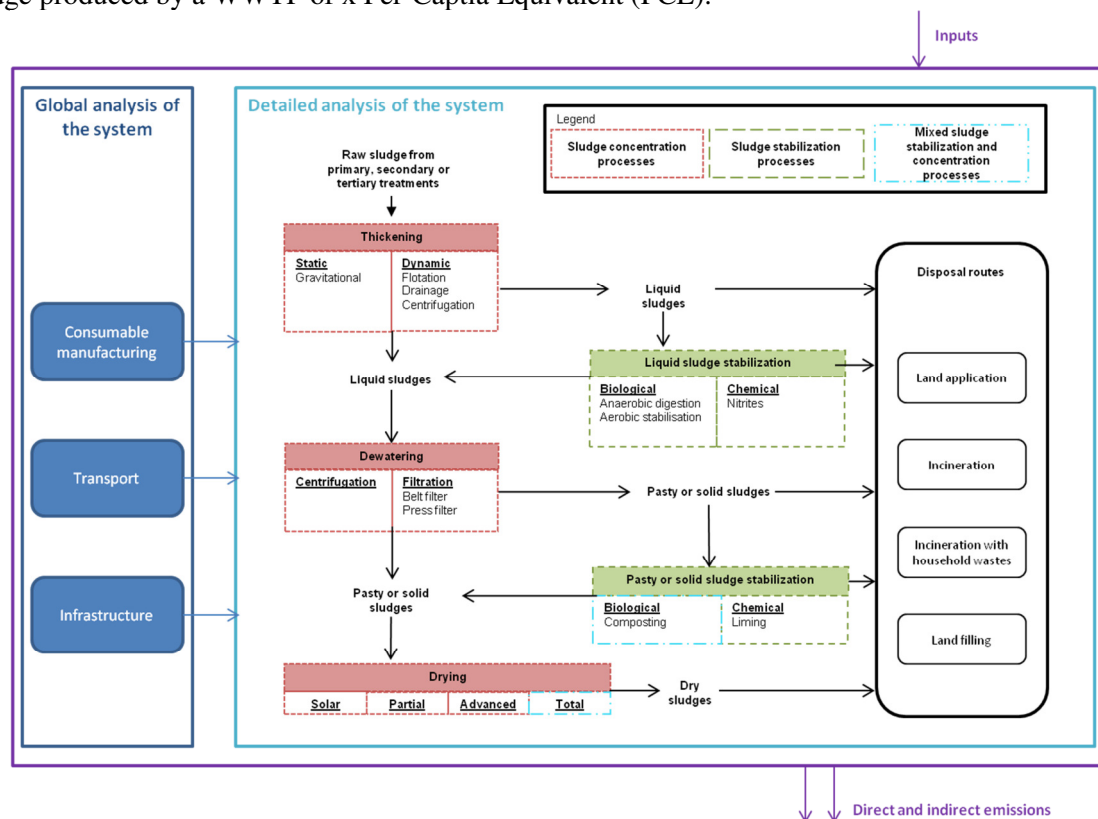


Figure 1. System boundaries

Calculation example of GHG emissions for sludge land spreading

During land spreading, N₂O emissions are linked to soil activity. In ^GE₅TABoues tool, we discerned emissions from liquid sludge, limed sludge, composted sludge, dry sludge and emissions from other types of sludge and mineral fertilizers.

Emissions from liquid, limed, composted and dry sludges come from the ECODEFI project (ANR Precodd, 2007-2011) (Pacaud *et al.*, 2009) (Table 1).

Table 1. N₂O emissions for liquid, limed, composted and dry sludges

Type of sludge	N ₂ O emissions (kg N ₂ O / ton)
Liquid sludge	0,0294
Limed sludge	0,0500
Composted sludge	0,0500
Dry sludge	0,2875

N₂O emissions from other types of sludge and mineral fertilizers come from Gestim guidebook (Gac *et al.*, 2010). There are two categories of N₂O emissions (Table 2):

- Direct emissions coming from organic and mineral fertilisers spread on the soil,
- Emissions differed in the time coming from nitrate leaching and NH₃ atmospheric deposition.

Table 2. N₂O Emission factor for other types of sludge and mineral fertilizers

Type of emission	Factor emission	EF	Annual rate of N leached or volatilized
Direct emissions	0.0157 kg N ₂ O / kg N	EF(p)	
Indirect emissions – Leaching	0,0118 kg N ₂ O / kg N leached	EF(l)	30%
Indirect emissions – Atmospheric deposition	0,0157 kg N ₂ O / kg N volatilized	EF(v)	10% for mineral fertilizers 20% for sludge

GHG emissions for the other types of sludge and for mineral fertilizers are calculated according Equation (1):

$$\text{Eq (1) } N_2O \text{ emissions} = \text{Nitrogen supply} \times [\text{EF(p)} + \text{rate } N_{\text{leached}} \times \text{EF(l)} + \text{rate } N_{\text{volatilized}} \times \text{EF(v)}]$$

Specific hypotheses for sludge land spreading

Land spreading

During sludge land spreading, some methodological problems are highlighted regarding fertilisation aspects: sludge application in fields has to be completed with mineral fertilizers due to the lack of nitrogen provided by sludge to fulfil the plant needs. In ^GE_sTABoues, we propose to solve this methodological problem with three hypotheses:

- (i) We considered N₂O emissions for both sludge and mineral fertilizers applied to complete the fertilisation,
- (ii) We considered emissions from mineral fertilizers manufacturing,
- (iii) We considered that fuel consumed for mineral fertilizers application is negligible compared to fuel consumed for sludge application.

Sludge transport and fuel consumption

Sludge transport refers to transport between wastewater treatment plant and the field with a 120 kW tractor equipped with a high capacity spreader. Sludges are transported on 40km. Fuel consumption refers to fuel consumed during sludge loading and land spreading.

Infrastructure

Infrastructure emissions were accounted for each process involved in the system and globalized at the whole WWTP scale regarding 3 WWTP classes (<10 000 PCE, between 10 000 and 100 000 PCE, > 100 000 PCE).

Avoided emissions

Avoided emissions represent emissions that could have occurred if mineral fertilizers were used instead of sludge and CO₂ sequestered in soil after sludge land spreading.

Studied system

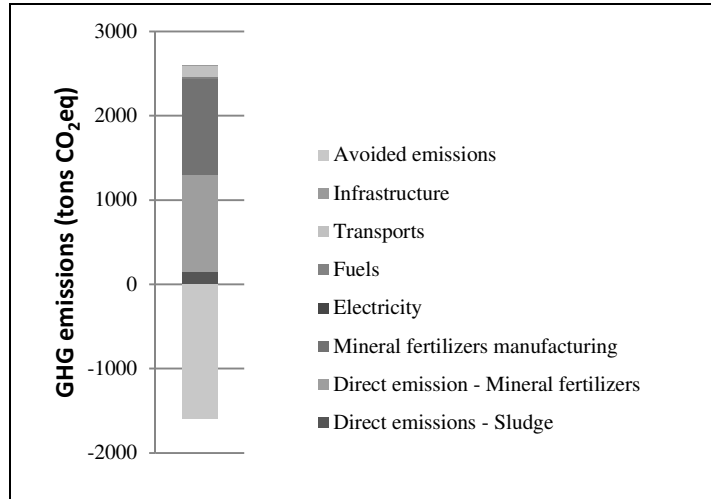
To underline the importance of these assumptions, we conduct a study to assess GHG emissions of sludge land spreading. The sludge come from a 380 000 per capita equivalent WWTP and represent 4 630 tons of dry sludge produced during one year.

Results

Results on sludge land spreading

During land spreading, we can discern different types of emissions:

- Direct emissions (sludge and mineral fertilizers): 1296.2 tons CO₂eq,
- Mineral fertilizers manufacturing: 1146.6 tons CO₂eq,
- Fuels: 13.2 tons CO₂eq,
- Transports of sludge: 139.6 tons CO₂eq,
- Infrastructure: 0.04 tons CO₂eq,
- Avoided emissions: -1593.3 tons CO₂eq.



Direct emissions and mineral fertilizers manufacturing are responsible for the most quantities of emitted GHG (94%).

Specific results on direct emissions and mineral fertilizers manufacturing

Direct emissions represent 1296.2 tons CO₂eq. Among those emissions, we can discern direct emissions from sludge (144 tons CO₂eq) and direct emissions from mineral fertilizers (1152 tons CO₂eq).

If we consider emissions from mineral fertilizers manufacturing that represent 1146.6 tons CO₂eq, we can say that almost all emissions due to sludge land spreading come from the consideration of mineral fertilizers in our system boundaries: 88% of total emissions during land spreading and more than 60% on sludge treatment and disposal routes were related to mineral fertilisers accounting.

If we choose to not taken into account emissions from mineral fertilizers in the system boundaries, GHG emissions from sludge land spreading are insignificant. Regarding these two aspects, we suggest to take into account both sludge and mineral fertilisers emissions in order to have a complete overview of sludge impact when it is used as fertiliser (as sludge is rich in P and poor in N, N fertiliser are needed to fulfil the plant needs).

Conclusion

As it is show in this example, system boundaries definition is very important to conduct an environmental assessment of GHG emissions during land spreading. Depending on the boundaries, possible misunderstanding in conclusions of environmental assessment can occur. Further work is ongoing to the influence of system boundaries of sludge land spreading of global warming and other life cycle assessment impact categories results.

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