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ENVIRONMENTAL IMPACT OF FARM-SCALE COMPOSTING

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INTRODUCTION

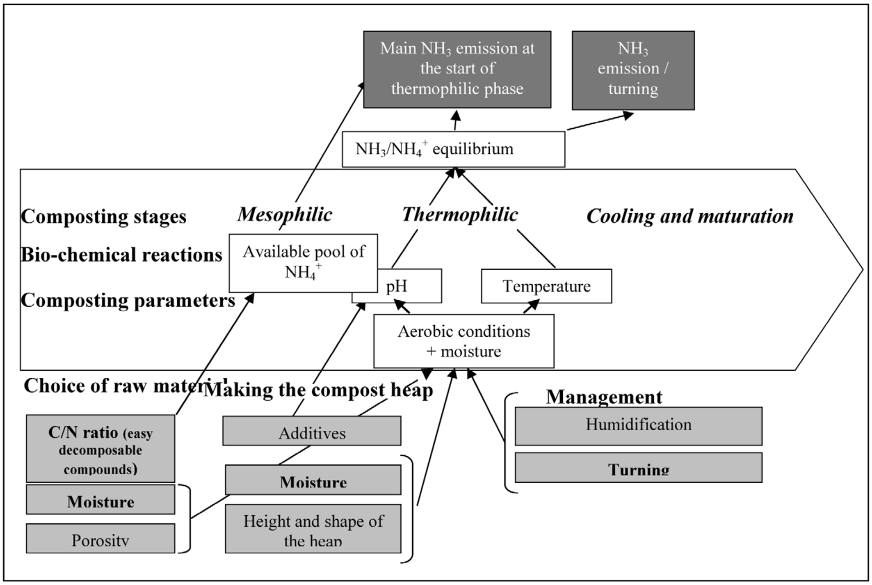
In the last decades, farm-scale composting meets an increasing interest among agronomists for different reasons, e.g. as a solution to water pollution problems due to intensive use of farmyard manure, decrease of soil organic matter in intensive cropping areas (Leclerc, 1995). However, many authors show that composting may induce environmental pollution by nutrient losses (Kirchmann and Witter, 1989; Martins and Dewes, 1992). Risks due to farm composting for two compartments of the environment: water and air have been identified. Impact on air is the most important one (Sommer and Dahl, 1999).

We developed an indicator to assess environmental impacts of farm-scale composting based on the INDIGO method (Bockstaller et al., 1997). Emissions of 3 gases: methane (CH_4), nitrous oxide (N_2O) and ammonia (NH_3) are investigated. The risk is expressed by an index on a scale varying from 0 (strong impact) to 10 (weak impact). The farm-scale composting indicator is built with 3 modules I_{NH3}, I_{CH4} and I_{N2O} which represent evaluation of the environmental impacts of the 3 considered gases. To explain the construction of this kind of indicator, we have developed in this paper I_{NH3} which assesses the risks of NH_3 emission due to farming techniques.

CHOICE OF INPUT VARIABLES

Input variables have to be easy to record, without direct measurements or field analyses, and relevant according o their involvement in the mechanism of gas emission (in this case NH3, Cf. Figure 1)

Figure 1: Composting process and ammonia emission



From a bibliographic review, it comes out that emission of ammonia depends on three factors in the composting heap : availability of NH_4^+, high temperature and pH.

The first factor is linked to the nature of the raw material : a material with low C/N presents nitrogen excess compared to carbon compounds and so NH_4^+ available to volatilize. According to the literature, C/N ratio inferior to 30 enhance ammonia emission. A high content of easily degradable compounds (C and N) increases the availability of NH_4^+ during the composting. Degradability of raw material may be assessed by lignin content.

Temperature and pH increase during composting process because of energy and basic compounds produced by micro-organism activity. Good aerobic conditions in compost heap and optimum moisture content (40-60 %) promote micro-organisms activity. Therefore, all the practices which provide aerobic conditions are sources of ammonia emission : addition of bulking agent which enhances porosity of heap, adequate height and shape of the heap and windrow turning.

Moisture content of raw material reflects porosity of the compost heap and hence aerobic condition while making its. Frequency and number of windrow turning provide information on aerobic conditions during the composting process. Indeed ammonia emission is enhance by high frequency of turning at the beginning of the process (NH_4^+ production phase), and each turning release ammonia produced within the heap.

We did not take into account several factors : (i) Height and shape of the heap because of the less of variability of those variables (majorities of the compost heap are windrow with a height of 1,5 m to 2 m) (ii) Humidification of the compost heap which is hard to assess, because of the lack of information (iii) composting additives because no scientific data proves efficiency of additives used by farmers (iv) Porosity, hardly calculate, is taken into account by moisture content calculation.

To sum up, the variables involved in the calculation (in bold in Figure 1) are: the C/N ratio with the degradability of C compounds, the moisture content of the raw material and the turning of the windrow (frequency and number).

AGGREGATION

Because of the heterogeneity of the variables, we used an expert system based on the fuzzy logic to aggregate them. Fuzzy logic is a mathematical tool which allows to :

- aggregate mixed input variables,
- solve the problem of limit of classes.

The construction of an expert system based on fuzzy logic may be split up in three steps:

1. Construction of the decision tree

Figure 2: The effect of the input variables on the values of the conclusions of the decision rules according to their membership to the fuzzy sets Favourable (non-shaded boxes) and Unfavourable (shaded boxes).

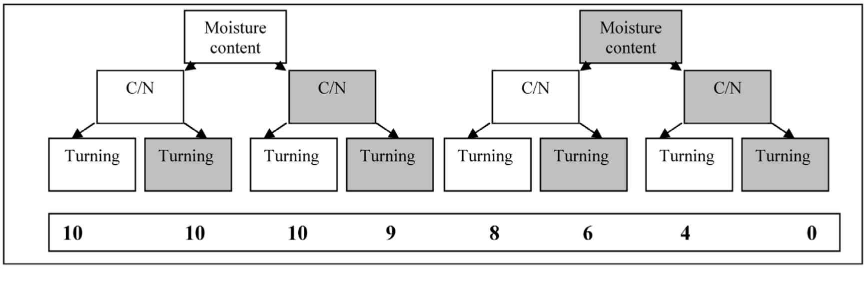


Figure 2 shows expert system : each branch of the decision tree represents a decision rule, expert or literature information give it a value between 0 (strong ammonia emission) and 10 (no emission). The shaded box is unfavourable value, i.e. conditions where the involved variable enhances maximum ammonia emission. The non-shaded box is favourable value, i.e. conditions where no ammonia emission occurs. Aggregation is realised by using Sugeno's inference method, i.e. *'If - Then'* rules (Werf and Zimmer, 1998). In linguistic term first branch of the decision tree can be read as : '**If** moisture content is favourable **and if** C/N is favourable **and if** Turning is favourable **then** value of the indicator is 10'

2. Definition of the fuzzy class for each variable

Between both classes (favourable or unfavourable), we defined intermediate class which is named fuzzy class. This one represents a class where information are not accurate. Table 1 gives class limits of the classes for the three involved variables.

Table 1 : Class limits and membership function of the 3 involved variables.

Variables	Favourable class	Unfavourable class
C/N (Lignin content)	> 35	< 5
Moisture content	< 40 % (composting don't start) or > 90% (anaerobic)	45 – 55 % (optimum moisture content for maximal biological activity)
Turning	No turning to one all the 3 weeks	More than 5 turning the first week

3. Definition of the membership functions in the fuzzy class

Membership function serves to give membership degree to one or other class to the involved variable. These membership degrees allow to aggregate values of the variables which are not totally favourable or unfavourable.

At last, we got a score from 0 to 10 assessing the risks for NH_3 losses according to the compost management. The output variable is qualitative. The value 7 serves as a reference, i.e. farm-scale composting cause serious environmental problems below this value. Scientific consensus was chosen to build this reference.

EXAMPLE OF CALCULATION

This study was also performed for the modules assessing CH_4 and N_2O emission. These ones are built in the same way as the NH_3 module.

This tool gives notes for various types of composting processes. Some results of 3 scenarios are presented in table 2. Composting indicator assesses the impact of these scenarios for the 3 gases (NH_3, CH_4 and N_2O). For the first scenario, the value of the indicator were about 7 for the 3 modules. For the second scenario, the score was lower for NH_3 module (1/10) and higher for the two others (9/10). The third scenario got a high score (9/10) for the NH_3 module but a low one for CH_4 and N_2O (1/10).

This evaluation shows antagonism between NH_3 emissions and those of greenhouse effect gases (N_2O and CH_4). It can help to find a technical compromise minimising emissions of the 3 gases as proposed in the scenario 1.

Table 2 : Evaluation of three different composting processes

		Composting management scenarios	NH_3	CH_4	N_20
SCENARIO N°1	**Choice of raw material**	Dairy cattle manure (free-stall housing with > 7 kg of straw/ LU/day) C/N = 20 to 30 Good porosity From 70 % to 80 % of moisture content	7	7	7
	Making the compost heap	During spring period Windrow on field Height = 1,5 m No addition of water Straw cover during active phase			
	Management	Turning : twice, one month Duration of composting : 2 months Geotextile cover during maturation			
SCENARIO N°2	**Choice of raw material**	Poultry manure C/N = 10 to 15 Good porosity 25 % of moisture content	1	9	9
	Making the compost heap	During winter Windrow on concrete platform with water recovery and roof Height = 1,5 m Addition of water : to 50 % moisture content			
	Management	Turning : seven times once a week Duration of the composting period = 2 months			
SCENARIO N°3	**Choice of raw material**	Cattle manure (with low straw content < 3 kg) C/N < 20 Low porosity About 80 % of moisture content	9	1	1
	Making the compost heap	Starting date: spring Windrow on field Height = 2 m			
	Management	Turning = once, while making the pile Duration of the composting period = 1 year			

CONCLUSION

Last steps of indicator construction are sensitivity tests and validation. Nature of the raw material (C/N, moisture content etc.) represents the most important variables in assessment of environmental impact. So, choice of the raw material seems to be the most important stage of composting process. Now, we are working on indicator validation by comparing output variables with experiment results (only NH_3 and N_2O data) and literature data. This stage is the most critical because of difficulties to validate multivariable tool.

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