A management model for pathogen abatement in animal slurry in view of its agronomic use

Un modèle de gestion des lisiers permettant l'abattement en pathogènes en vue de son utilisation agronomique.

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Abstract

An important concern connected with the agronomic use of animal slurry is related to hygiene, both animal and human health. It is therefore of paramount importance to adopt techniques and operational criteria that minimise the potential risk of disease transmission. Only information related to the survival of micro-organisms during individual phases of slurry handling (storing, aerobic or anaerobic treatment, etc.) is available.

For this reason, we developed and evaluated a model in which the influence of the slurry management system on pathogen survival is considered (Salmonella dublin and S. typhimurium).

By using the model, it is possible to evaluate, taking into account the variability, the consequences of different management options. For instance, we determined that for cattle slurry with a total solids concentration of 9%, the storage period required to eliminate S. dublin is approximately 150 days, but it decreases to 120 days if solid-liquid separation is utilised. Although our preliminary results are very encouraging, the model needs to consider additional information on the behaviour of different micro-organisms and to be calibrated to specific conditions under which it can be utilised.

Key words**:** manure handling, pathogen control, management models

Résumé

Un problème important lié à l'utilisation agronomique des lisiers concerne les aspects hygiéniques, à la fois pour la santé humaine et animale. Il est par conséquent particulièrement urgent d'adopter des techniques et des critères de gestion qui minimisent le risque de transmission des maladies. Seules les informations concernant la durée de vie des microorganismes au cours des étapes particulières de gestion des effluents (stockage, traitement aérobie ou anaérobie, etc...) sont disponibles.

Nous avons donc développé et évalué un modèle dans lequel l'influence du système de gestion du lisier est relié à la survie des pathogènes (*Salmonella dublin et S. typhimurium*)

En utilisant ce modèle, il est possible, en prenant en compte la variabilité, d'évaluer les conséquences des différentes alternatives de gestion. Par exemple, nous avons déterminé pour le lisier bovin d'une teneur en matière sèche de 9%, que la période de stockage nécessaire pour éliminer *S. dublin* est approximativement de 150 jours, mais est réduite à 120 jours si un système de séparation liquide-solide est mis en oeuvre. Bien que nos résultats préliminaires soient encourageants, le modèle doit pouvoir incorporer d'autres informations sur le devenir des différents micro-organismes et également doit être étalonné en conditions réelles d'utilisation.

Mots-clés : gestion déjections, contrôle des pathogènes, modèles de gestion.

1. Introduction

There is an increasing interest in the relationship between agriculture and the environment, in particular as far as the agronomic use of animal manure and pesticides are concerned. On one hand, there is a growing demand for new research and scientifically-based advice, that is, guidelines to help farmers and agricultural advisors in their manure management choices. On the other hand, politicians seek reliable information to be able to draw up realistic regulations that can minimise the impact of agriculture on the environment.

One aspect receiving particular attention in the context of the agronomic use of animal manure is the control of hygienic conditions during the handling of animal manure.

Information on the behaviour of micro-organisms in the various handling stages (that is, separation storage, aerobic or anaerobic treatment, *etc*.) is now available. However, comparable information does not exist from a system's point of view. Therefore, we made an attempt to gather and link experimental data in a system representation. This led to the definition of several models able to identify the main factors that can be modified to control the hygienic aspects of farm manure handling.

2. Material and methods

First we devised a general model (Figure 1) describing the possible stages of manure from the animal to the field, and identifying where changes in the bacterial characteristics of the manure are possible. Secondly, we analysed the results obtained in various experiments on micro-organism survival in manure. These data were organised to clearly identify in each study the test conditions and the factors influencing survival time of the micro-organisms (Figure 2). Specifically, we highlighted the initial concentrations of micro-organisms, temperature, total solids content, and pH of the manure on pathogen survival time. We utilised linear regression analysis in which pathogen survival time was the dependent variable and each survival factor was the independent variable to identify statistically ($P<0.05$) significant correlations. These correlations were then entered into the management model to facilitate their application to practical situations. By the way, models were devised both for swine and cattle.

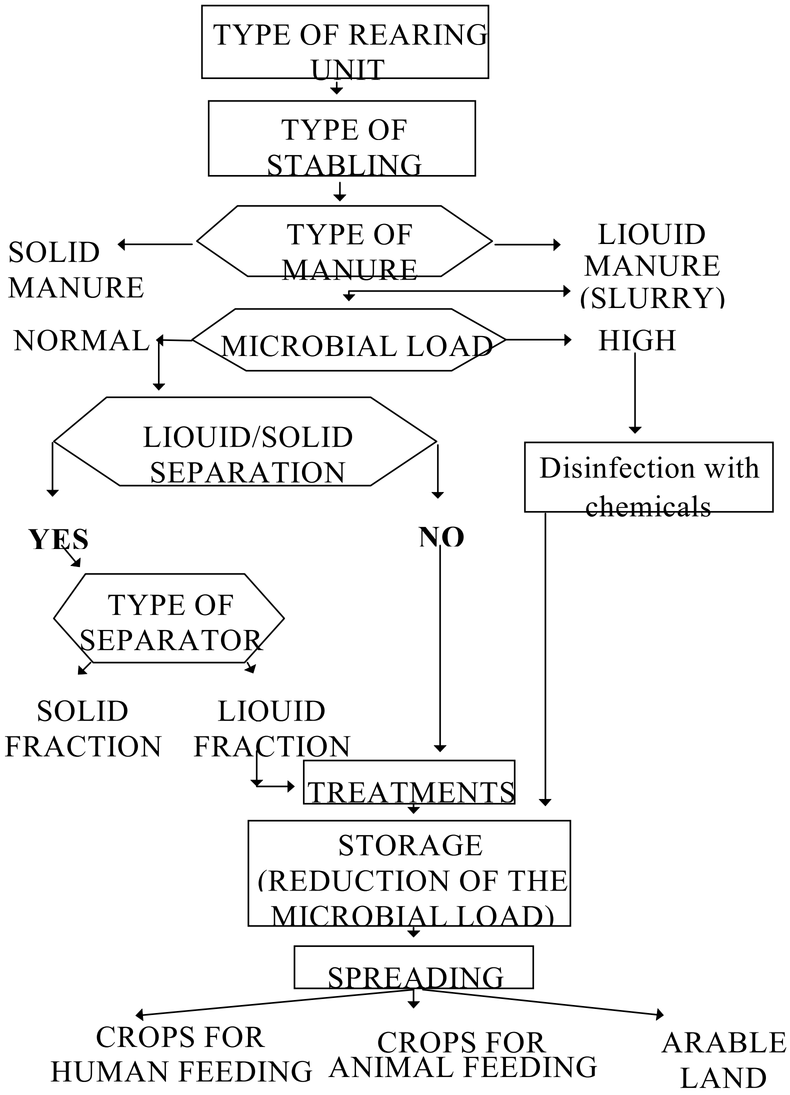

Figure 1

General and simplified model describing the slurry cycle from production to the field

3. Results and discussion

Our management models are based on the analysis of the different stages of animal manure handling. Within each stage, the initial conditions (e.g. the concentration of the micro-organisms) and the values referring to factors influencing survival time or affecting pathogen concentration in manure (e.g. temperature, dry matter content, pH, duration of the handling process) can be identified. In general terms, the models define an input-output function (IOF) linking the initial conditions and the survival factors in order to evaluate the final conditions.

The final conditions of each stage of the handling process represents the initial conditions of the subsequent stage. By introducing the IOF's to describe pathogen survival at various stages of manure handling, it is possible to evaluate the hygienic state of the manure when it has to be agronomically utilised, provided that the starting conditions (i.e. the infectious state of the herd and the manure handling techniques used) are known.

To illustrate the development and use of our models we present an example based on *S. dublin* and cattle slurry in Figure 3.

Survival time (days)	**Initial concentration of microorganism UFC/ml**	**Final concentration of microorganism UFC/ml**	**pH**	**Temperature**	**D.M. (T.S.)**	**References**	**Notes**
132	1.000.000	0	7,4	5	4,7	39	temperature
84	55.000.000	0	6,7	5	7	55	temperature
180	1.000.000	0	7,5	10	5,2	40	sterilized+ untreated
63	6.309.573	0	7,6	5	0,4	10	disinfectants
77	1.995.262	0	7,2	5	4,5	10	uncovered
114	130.000	0	7,5	10	5,7	39	pHmin.6,5
105	150.000	0	7,5	10	5,7	39	pHmin.7
113	180.000	0	7,5	10	5,5	39	serotype HWS51
90	340.000	0	7,5	10	5,5	39	serotype HWS51

Figure 2
Example of organization of the data collected from the various experiments

Our analysis revealed that during storage the dry matter content had the highest correlation with survival time of the bacterium, in agreement with findings reported by several researchers. The slope of the regression line shows that as slurry dry matter content increases, so does the survival time of *S. dublin* (Figure 3). On the basis of this relationship, it can be noted, for example, that in diluted slurries (dry matter contents of 1%-2%), the survival time of *S. dublin* during storage is 70-80 days, while in thicker slurries (6%-7% dry matter) survival time is about 120 days.

The same figure also contains the regression lines obtained by grouping data into three temperatures that are representative of the different seasonal conditions in temperate climates. It can be noted that with higher dry matter content, survival times at low (1-6 ^oC) and moderate (10 ^oC) temperatures tend to develop and be similar to the general regression. Larger deviations are shown with thicker slurry but with lower dry matter content and for higher temperatures (20-30 ^oC).

We have thus redesigned the original models to these new assumptions (Figure 4).

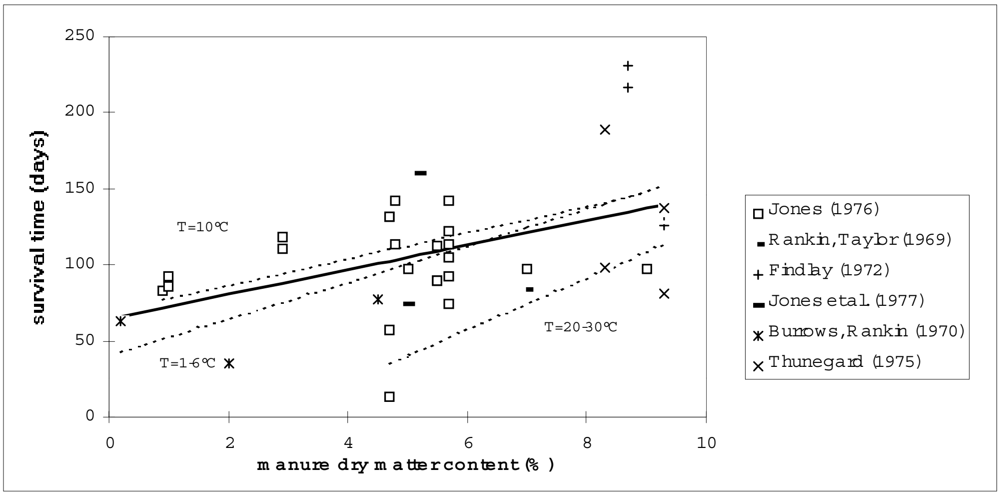

Figure 3
Relationship between survival time and manure dry matter content for Salmonella dublin during storage.

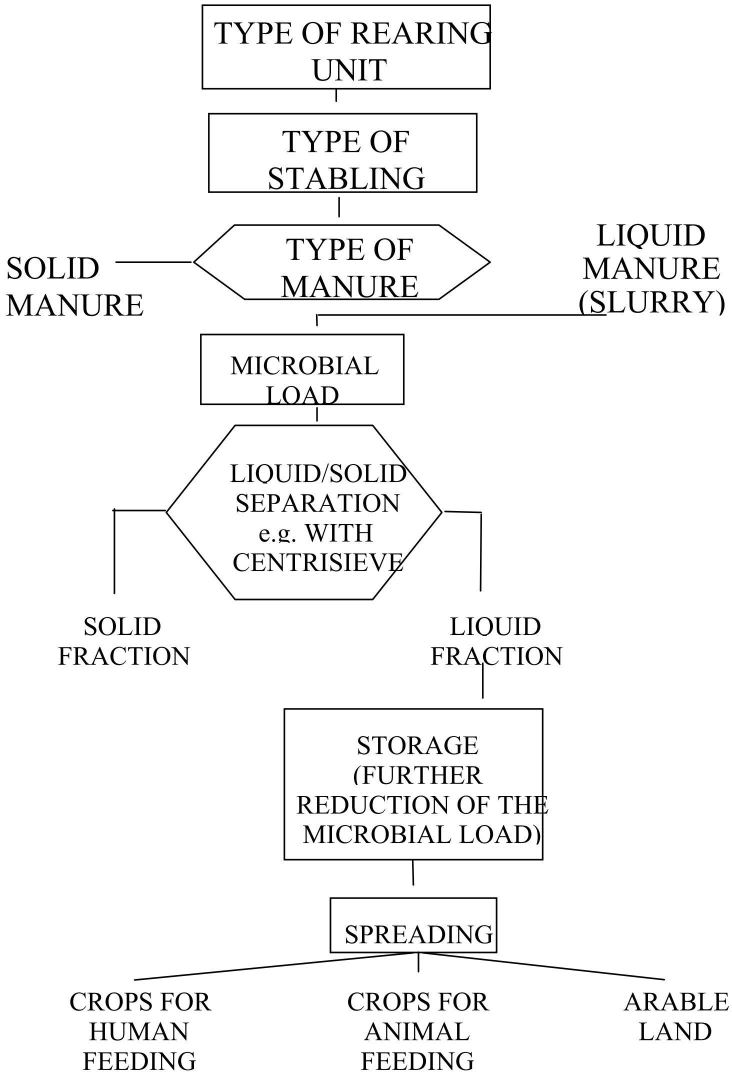

Figure 4
The new model designed taking into account the factors influencing microbial survival time.

As an example of how to apply these results to practical situations, let us consider a manure handling practice in which slurry, produced by cattle on slatted floors (dry matter content approximately 9%), flows directly into a storage tank. After storage the slurry is spread on arable land. Using the relationships we developed, we would recommend that a slurry storage time of 150 days should be provided in order to reduce S. dublin concentrations to acceptable levels in winter. However, by using a liquid-solid separator with a 30% efficiency, the dry matter content could be decreased to 6% and, as a consequence, the storage time required to achieve an acceptable hygienic standard could be decreased to 120 days. In the summertime, the higher ambient temperatures would halve this value.

The Figure 5 also shows clearly that the models we derived can help evaluate different slurry management choices according to hygienic considerations. Such choices can have significant economic effects on investment and running costs. Obviously, it would be necessary also to check the compatibility of individual management decisions with the agronomic requirements on slurry spreading. Politicians or those in charge of environmental protection could use these results either to develop slurry management criteria, or as a basis to propose economic incentives to facilitate adoption of the criteria by farmers.

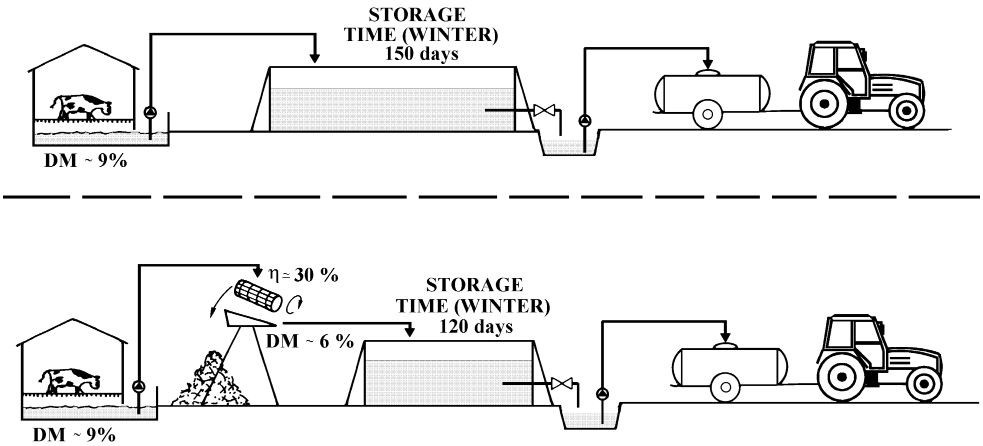

Figure 5
Possible consequencies on slurry management hardware derived by the use of the model devised.

4. Conclusions

Despite these encouraging preliminary results, widespread implementation of the proposed management models requires further investigation to incorporate the behaviour of additional micro-organisms and to calibrate the models to the specific conditions in which they would be utilised. An extension of the models to include different kinds of pathogens (*e.g.* viruses, parasites, and mycetes) is also needed. Additional micro-organisms must be taken into account and a comparison with the results obtained in this study must be made in order to find management solutions able to give an overall reduction in the pathogenic load, rather than address only a specific agent. To go further in this direction, it is also necessary to consider both the risk (damage in economic terms) posed by a specific agent, and the frequency of infection events in a specific area. By following such an approach, it will be possible to take into real consideration the hygienic problems associated with animal manure management, to evaluate the possible on-site and off-site dangers resulting from the use of this material, and to devise practical methods by which to keep risks within acceptable limits.

5. References

References, consisting in 76 titles, are available from the authors.