Reducing the constraints of environmental legislation on pig production by using a selection of manure management technologies

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Abstract
Limits on land applications of manure N and P can constrain the livestock production capacity of a farm. Modelling was used to assess the use of slurry management technologies on a pig-producing ('donor') farm to export slurry products to a farm ('recipient') that had the capacity to utilise the nitrogen (N) and phosphorus (P). Technologies investigated were screw press separation, ± solid fraction composting, centrifuge separation ± liquid fraction ammonia (NH_3) stripping. Regulatory constraints were imposed on donor and recipient farms on the application of a) slurry N, b) P, c) N and P and d) on donor farm NH_3 emissions. Separation had little effect on N losses per unit mass of slurry, but NH_3 stripping led to a reduction. Centrifuge separation allowed a greater increase in pig production than a screw press, especially with P regulation. NH_3 stripping was advantageous with N regulation or when combined with NH_3 scrubbing of pig housing ventilation air, when donor farm NH_3 emissions were constrained.

Introduction
Livestock production is often concentrated geographically, leading to a large localised production of manure. Excessive land application of manure can threaten the aquatic environment. Livestock housing, manure storage and field application of manure leads to emissions of NH_3 which is an atmospheric pollutant. One measure used to reduce these environmental impacts is to limit the rate of application of manure nutrients to land. In Europe, the main emphasis has been on N (e.g. via the EU Nitrates Directive). However, since P loss is a threat to freshwater aquatic ecosystems, this element is of increasing interest (e.g. EU Water Framework Directive). The local availability of farmland on which to utilise slurry can limit farmers' ability to maintain or increase livestock production. Consequently, there is interest in technologies such as slurry separation that enable the economic transport of slurry nutrients over longer distances and a better balanced nutrient composition. The objective of this investigation was to assess the consequences of using a range of slurry management options that would enable pig producers to increase production under increasingly stringent environmental constraints. Four scenarios for the regulation of pig production are considered, three relating to the protection of aquatic environments and one to the atmospheric environment. Four slurry management options were investigated that would enable N and P to be exported from a donor farm. The consequences of using each slurry management option within each regulatory regime was assessed in terms of the permissible annual pig production on the donor farm, the area required on the recipient farm and the side-effects on non-targeted pollutants.

Material and Methods
Regulatory scenarios
Four regulatory scenarios were developed, representing progressively stringent control over the losses of N and P from pig production. The scenarios were:

1. **N regulation** The maximum annual application of slurry N is 170 kg ha^{-1} yr^{-1}, as permitted by the EU Nitrates Directive.
2. **P regulation** The maximum annual application of slurry P was limited to the annual offtake of P by the crops.

3. **N & P regulation** The annual application of slurry must simultaneously comply with 1. and 2.
4. **+No NH3 increase** The NH_3 emissions from the donor farm must not increase following any increase in production permitted by the other regulatory scenarios.

Slurry management options
The management options investigated were:

- Baseline - conventional slurry management with slurry storage in a slurry tank, followed by field application on the donor farm.
- SepS - Slurry separation with a screw press, with the solid fraction transported for field application on a recipient farm and the liquid fraction applied to fields on the donor farm. Separation efficiencies were 11% for ammoniacal N (TAN), 24% for organic N and 17% for P.
- SepC - Slurry separation with a centrifuge but otherwise as in SepS. Separation efficiencies were 14% for TAN, 61% for organic N and 71% for P.
- Compost - SepS plus windrow composting of the resulting solid fraction. This option produces a material that is less bulky, more easily handled and less odorous than the SepS solid fraction.
- Nstrip - Slurry separation as in SepC, plus NH_3 stripping of the resulting liquid fraction. The NH_3 stripping removes 95% of the TAN from the liquid fraction via absorption into H_2SO_4 and produces $(NH_4)_2SO_4$ which can be readily transported. All organic N from the liquid fraction is contained in a rejectate fraction. To all management options, acid air scrubbing to remove 85% of the NH_3 from the ventilation gases from pig housing is applied. The resulting liquid is applied as a substitute for mineral N fertiliser.

Model production system
A model production system was typical of Danish finishing pig production. The pigs were housed in ventilated pig housing with partially-slatted flooring. Good management was assumed for all options; slurry, liquid fraction, digestate and rejectate were assumed to be stored in tanks covered with a tent to reduce NH_3 emissions, solid slurry was assumed to be covered to reduce self-heating and compost was assumed to be well aerated. Slurry, liquid fraction, digestate and rejectate were applied to land by trailing hose in spring and the solid fraction and compost application were by broadcast spreading followed by rapid incorporation. The crop mixture by area on both the donor and recipient farms was 40% spring barley, 40% winter wheat, 10% winter rape, 10% winter barley, and grass cover cropping in the winter prior to the spring barley. The removal of P in crop products was assumed here to be 21.5 kg ha^{-1} yr^{-1}. To ease the interpretation of the results, the total field area of the donor farm was set to be 100 ha. Crop yield per hectare was assumed to be constant across all scenarios and slurry management options, as the same amount of crop-available N was applied in all cases. The crop-availability of N in each slurry product was assigned in accordance with the Danish standard values [1]. In situations where the regulatory scenario imposed meant that the slurry products were applied at rates below that necessary to supply enough crop-available N, it was assumed that the deficit was supplied by ammonium nitrate.

Modelling N and P flows and emissions
Each technology option was represented by a static mass flow model which followed the fate of N and P in the pig excreta deposited in animal housing. For N, the flows of ammoniacal and organic N were followed separately through the slurry management system. Emission factors for N gasses were taken from [2] and [3].

Modelling the effect of slurry management options within regulatory scenarios
The amount of N and P ex storage per pig produced was calculated for the slurry products (solid fraction, liquid fraction etc.) for the 5 slurry management options using a static model of N and P flows. In all cases, it was assumed that all the liquid slurry products (slurry, liquid fraction or rejectate) were applied to the donor farm and all the solid slurry products (solid fraction and compost) were exported to the recipient farm. The $(NH_4)_2SO_4$ fraction was applied in an area with low livestock density, separate from the donor or recipient farm. For the N, P and N&P regulatory scenarios, the maximum permitted annual pig production of the donor farm was obtained by dividing the maximum

permitted land application of the relevant nutrient by the amount of the same nutrient in the liquid slurry product ex storage. The area of land on the recipient farm was calculated by dividing the maximum permitted land application of the relevant nutrient by the amount of the same nutrient in the solid slurry product ex storage. For the +No NH3 increase scenario, the air scrubbing was employed in combination with all other slurry management options except Baseline. The NH_3 emissions from the donor farm were calculated by the static model. The maximum permissible pig production was calculated by dividing the total NH_3 emissions when using the alternative slurry management options by the total NH_3 emissions per pig produced when using the Baseline slurry management option.

Results

Separation generally had little effect on N losses per unit mass of slurry (Fig 1). However, NH_3 stripping led to a reduction of total N losses.

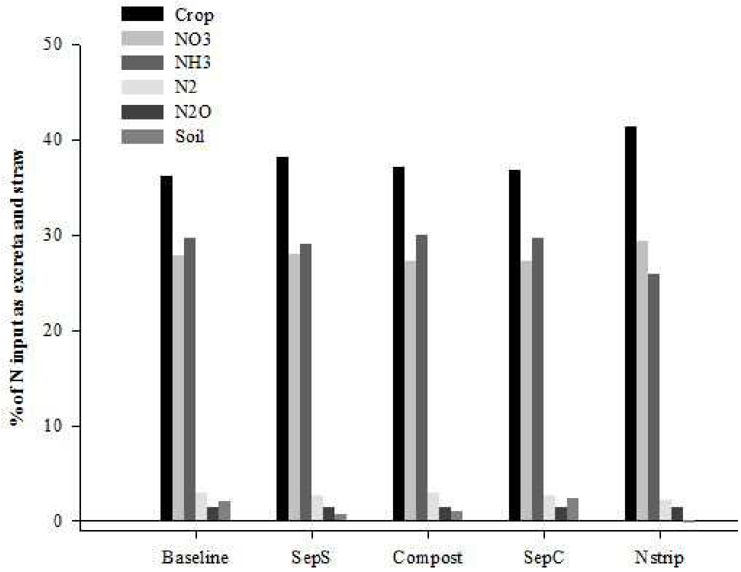

Figure 1. Partitioning of N input to crop yield, soil sequestration or losses to the environment

The use of centrifuge separation allowed a greater increase in pig production than a screw press, especially with P regulation (Fig 2). The use of NH_3 stripping was only an advantage under N regulation or when donor farm NH_3 emissions were a constraint and it was used in combination with NH_3 scrubbing of pig housing ventilation air. However, the area of recipient farmland required to utilise the solid fraction was substantial when the centrifugal separator was used, especially in combination with NH_3 stripping (Table 1). If in addition to the solid fraction, the $(NH_4)_2SO_4$ captured by the NH_3 stripping is also considered to be organic manure within the context of the EU Nitrates Directive, the area required when using this option under the N regulatory scenario increases to 14 times the area of the donor farm.

Table 1. Area of recipient farmland (ha) required to receive solid fraction or compost

Slurry management option	N regulated	P regulated	N&P regulated
SepS	17	21	21
Compost	18	22	22
SepC	37	245	37
NH3 Strip	248	245	245

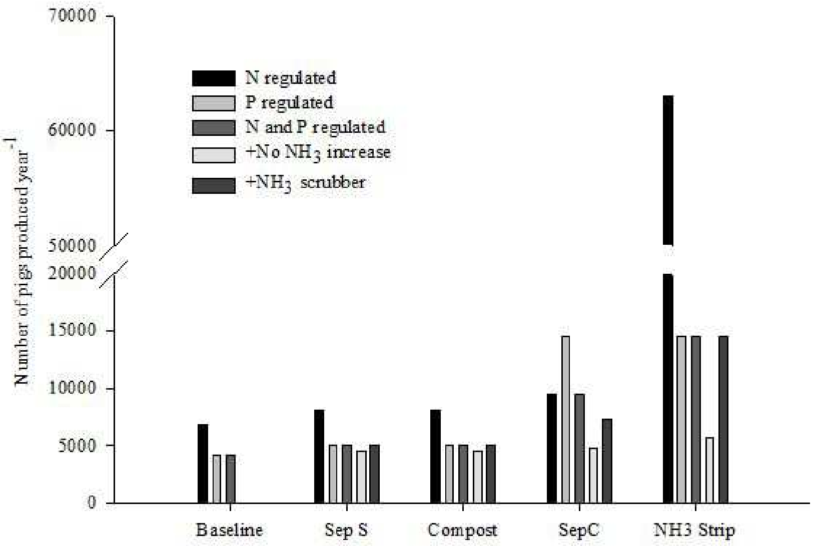

Figure 2. Maximum permissible pig production on a 100 ha farm under different regulatory scenarios

Regulating N alone led to a large P surplus on both the donor and recipient farm (Table 2).

Table 2. Farm P surplus (kg ha^{-1} yr^{-1}) for slurry management options under the N regulatory scenario

Slurry management option	Donor farm	Recipient farm
Baseline	14	-
SepS	13	20
Compost	13	20
SepC	-7	71
NH3 Strip	72	71

Conclusion and perspectives

The manure technologies studied were successful to varying degrees in permitting increases in pig production when nutrient application was limited by environmental legislation. However, they led to unwanted side-effects on the non-targeted nutrient. Imposing limits on the land application of manure nutrients resulted in a small negative production penalty when using composting. A range of manure management technologies are available that can be applied in varying combinations, depending upon the regulatory environment. However, regulators need to be aware that trade-offs between policy objectives may be necessary.

Acknowledgements

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