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The Institute of Agricultural and Fisheries Research

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IIASA

INNOVATION IN LIVESTOCK PRODUCTION: FROM IDEAS TO PRACTICE

Model-based tool to estimate the NH_3 emission reduction potential of adapted dairy housing systems

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PPTimer
20:00

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Motivation

1. NH_3 emissions in Flanders (Belgium) due to agriculture/livestock production is relatively high

2. In 2014, Flanders Government established PAS to address Natura2000

3. Certifications of emission reduction efficiency (RE) will be issued to adapted/new livestock systems

4. REs are determined via modeling and later validated with measurements

NATURA 2000

Flanders
is agriculture and fisheries

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Status quo of NH_3 emission modeling

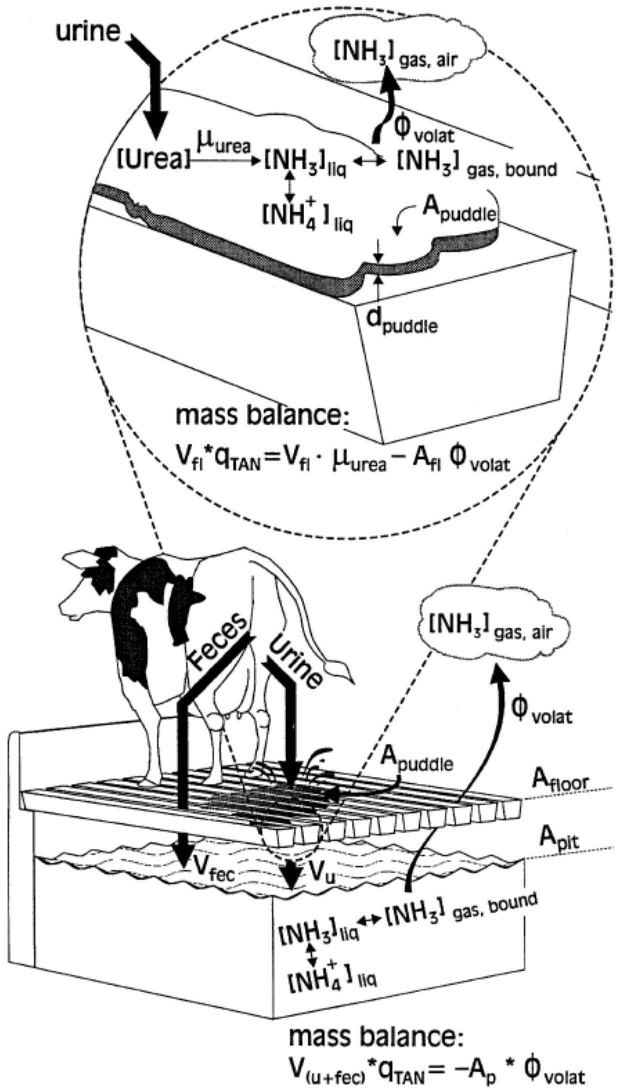


Fig 1. Components of the floor and pit modules (Monteny et al., 1998).

1. The mechanistic NH_3 emission model of Elzing & Monteny et al. 1997

2. Applied to a cattle barn by Monteny et al. 1998

3. In 2014, Snoek et al. published a literature review study and performed a sensitivity analysis

Objective

To adapt the NH_3 emission model with low-emission management techniques in order to predict emission reduction factors for new/adapted dairy cattle barns.

NH_3 Emission Model Principles

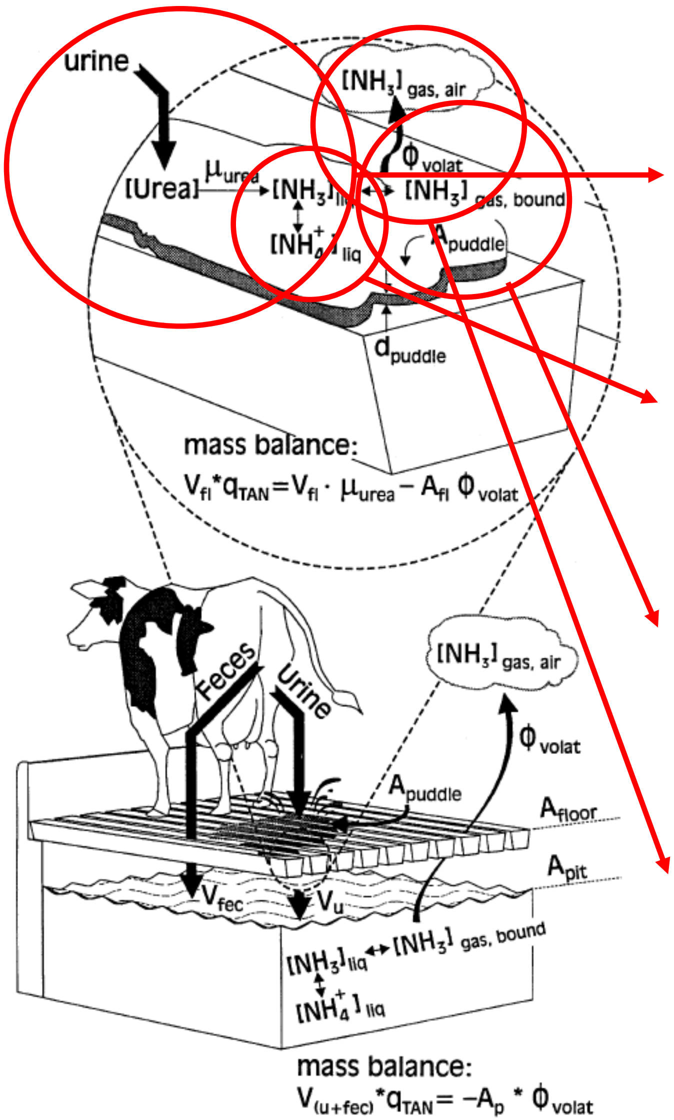


Fig 1. Components of the floor and pit modules (Monteny et al., 1998).

1. Breakdown of urea into NH_4^+ in the presence of urease
2. Dissociation of NH_4^+ into NH_3
3. Mass transfer of NH_3 within the concentration BL
4. Convective mass transfer of NH_3 to free airstream

Governing Equations

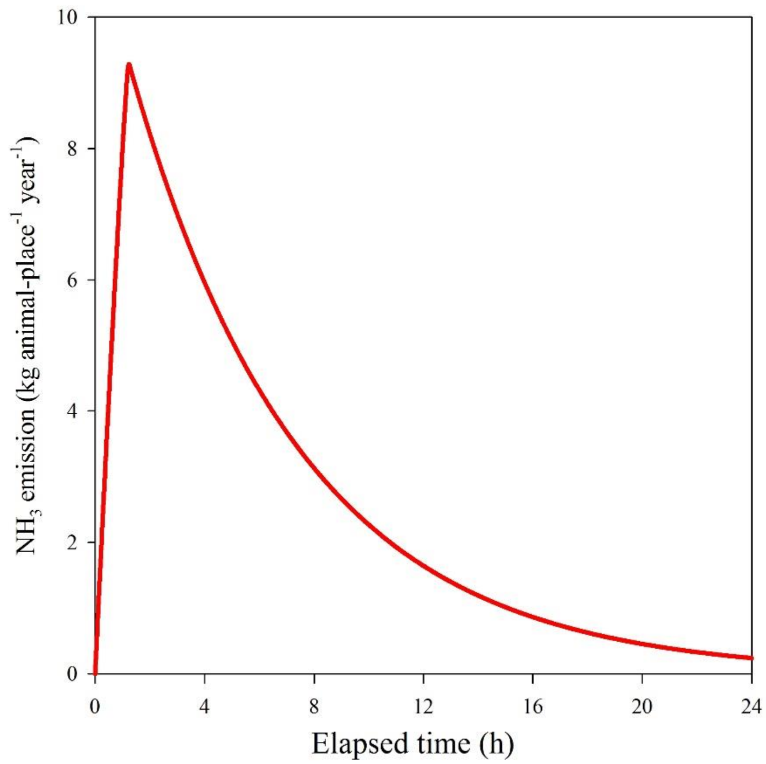
Modeling NH_3 emissions from a single urine puddle at floor (Elzing & Monteny, 1997)

$$\frac{d[C]}{dt} = 2\times\frac{d[U]}{dt} - \frac{E}{V}$$

$$E = \frac{k\times A\times[C]\times f}{H}$$

$$\frac{d[C]}{dt} = \frac{2\times S_m\times[U]}{K_m+[U]} - \frac{k\times A\times[C]\times f}{H\times V}$$

Fig 4. NH_3 emission dynamics from a single urine puddle.



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Governing Equations

Modeling NH_3 emissions at manure pit

$$E = \frac{17}{14} \times \frac{k \times A \times [TAN] \times f}{H}$$

Total barn NH_3 emissions:

$$E_{NH3,total} = E_{NH3,floor} + E_{NH3,manure\ pit}$$

Model 100% made in Microsoft Excel® and some VBA Macro

Defining the Standard Cattle Barn

- A standard cattle barn was considered as an ordinary system, traditionally used and commonly found in Flanders
- No relevant NH_3 emission mitigation strategy was considered
- Floor is slatted and no cleaning applied

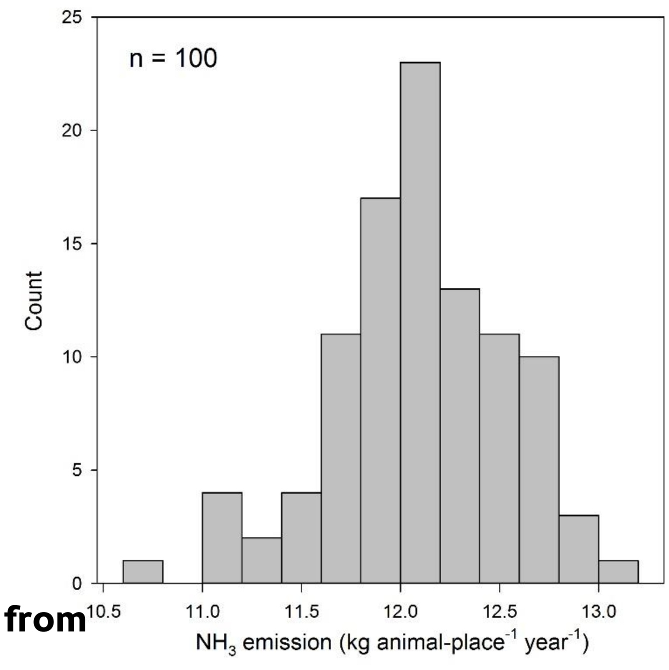

Fig 5. Histogram of NH_3 emission factor from standard system from multiple random urination times.

Applying management-based emission reduction strategies

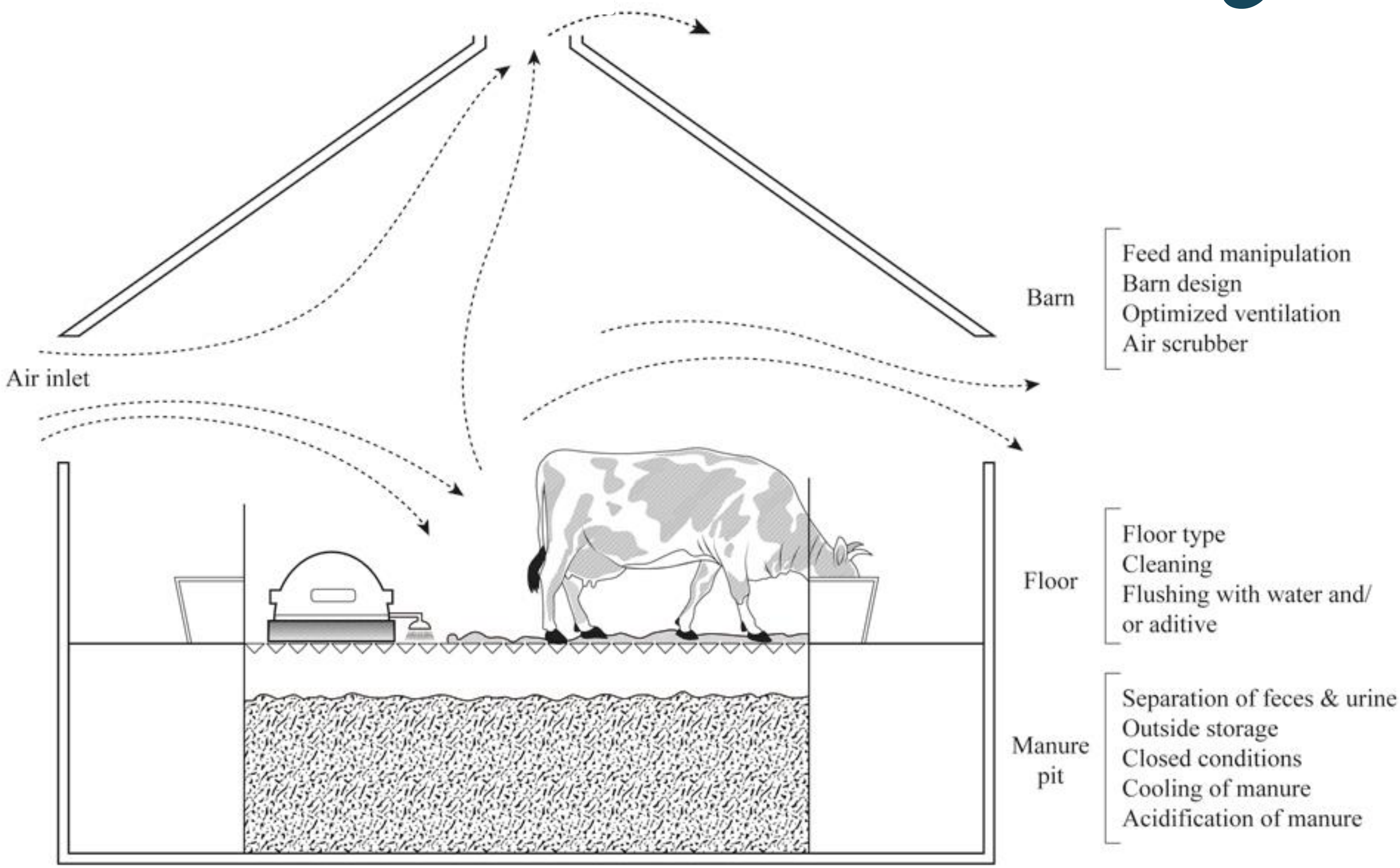

Fig 6. Compartimentalization of NH_3 emissions from a dairy cattle barn and places where mitigation strategies can be applied.

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Cleaning of Floor

- The shape of the curves was calibrated according to the Michaelis-Menten Dynamics, adjusted to experimental data by Dai & Karring (2014).

Information needed:
- Barn lentgh;
- Type of scraper (robot or cable pulled);
- Speed of scraper;
- Scraping frequency.

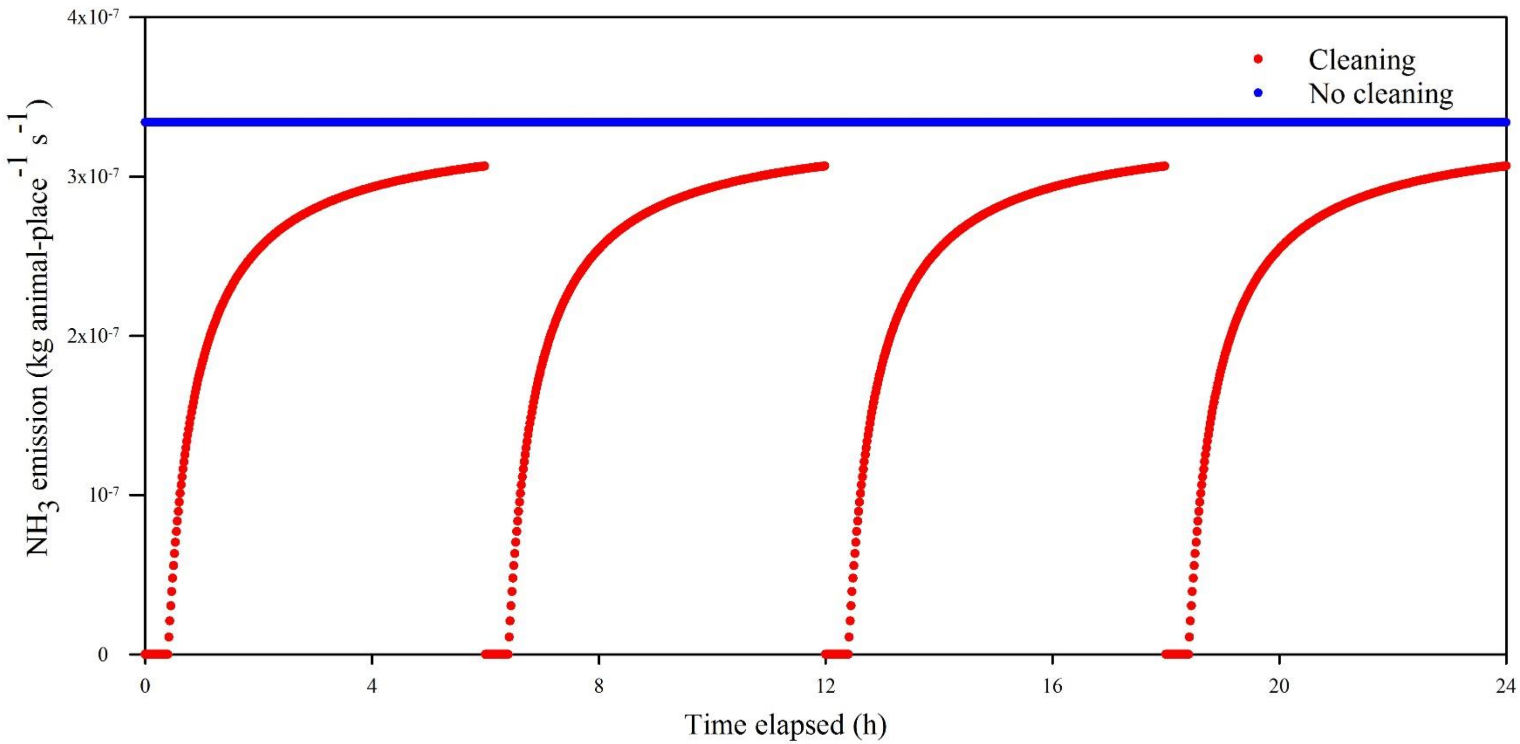

Fig 7. Emissions in an 'animal-place' basis with and without cleaning floor.

Flushing the Floor

Information needed:

- Flushing fluid volume and pH
- Estimate of how much of the flushing fluid remains on the floor

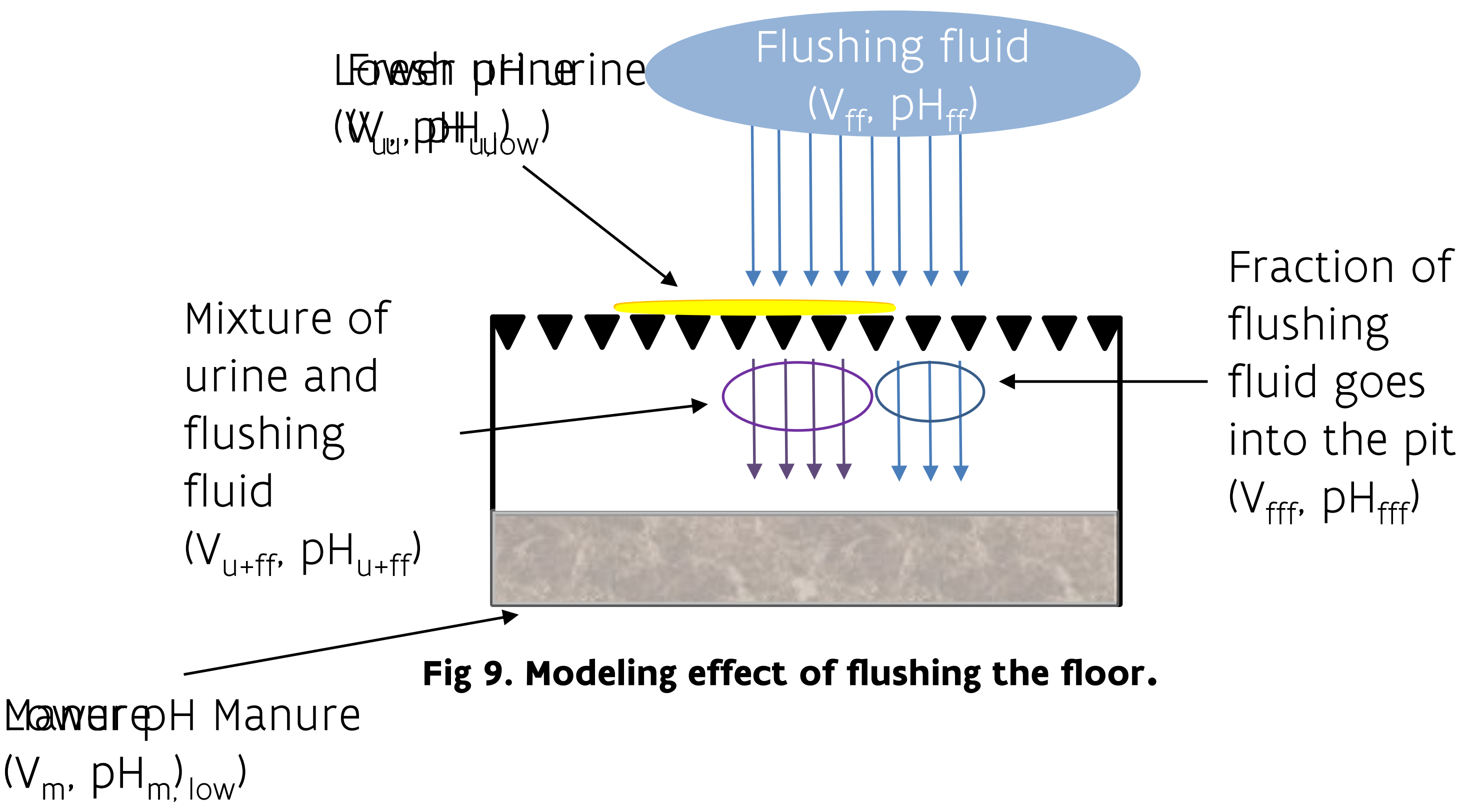

Fig 9. Modeling effect of flushing the floor.

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Modelling Different Floor Types

Information needed:

- Area and depth of the urine puddle for each type of floor

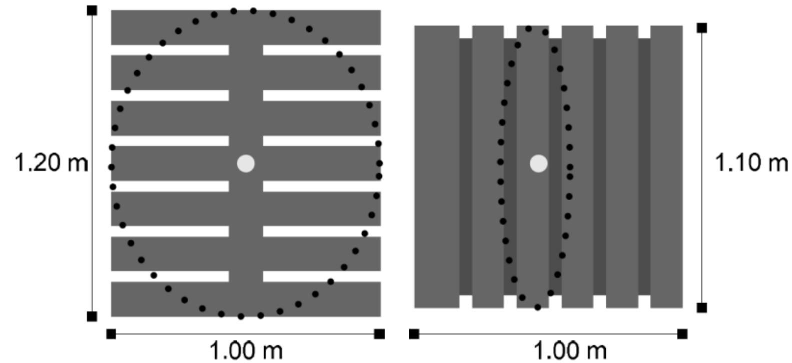

Fig 10. Different floor types allow for different urine puddle areas and depths (Source: Snoek et al., 2010).

Floor type	Urine puddle area (m^2)	Puddle depth (mm)
Traditional slatted floor	0.80	0.48
Solid floor (beton)	1.20	0.58
ECO floor	0.80	0.40
G3 floor	0.80	0.40
Slopped grooves	0.80 – 1.20	0.40
EA floor; G6 floor	0.80	0.27
Agra Matic floor	1.20	0.17
Groene Vlag floor	0.80	0.15

Table 1. Puddle area and depth for different floor types (Source: Monteny, 2015 – Personal communication).

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Global Sensitivity Analysis: Practical Implications

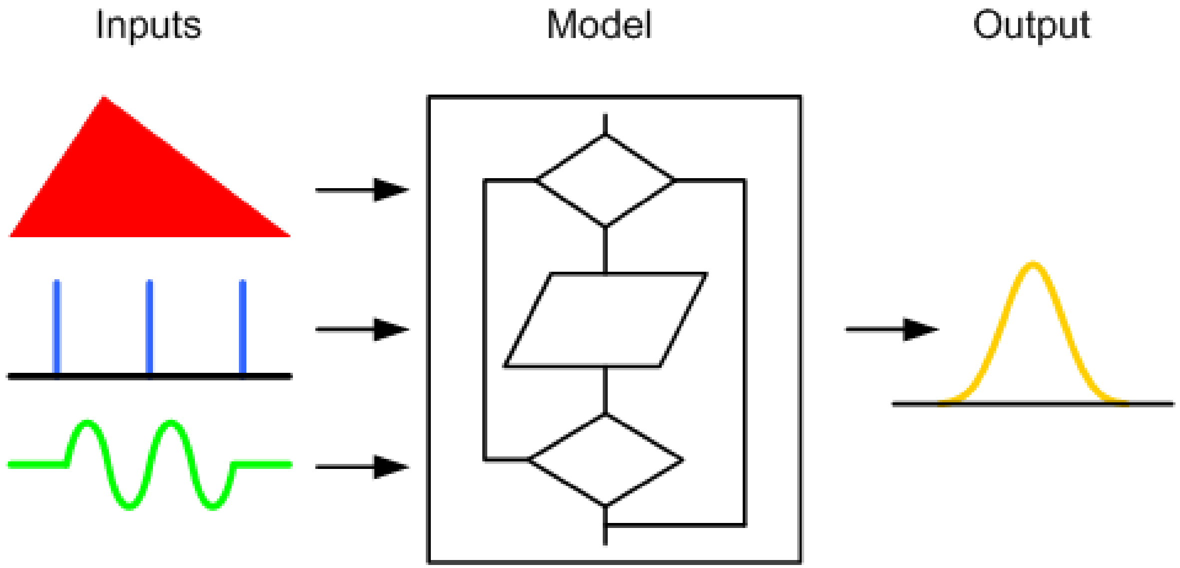

Fig 11. Graphical representation of the effect of different PDFs assigned to the model inputs on its output.

Benefits:

- Establish CIs
- Sort the most relevant variables out

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RESULTS: Defining the minimum number of iteractions for GSA

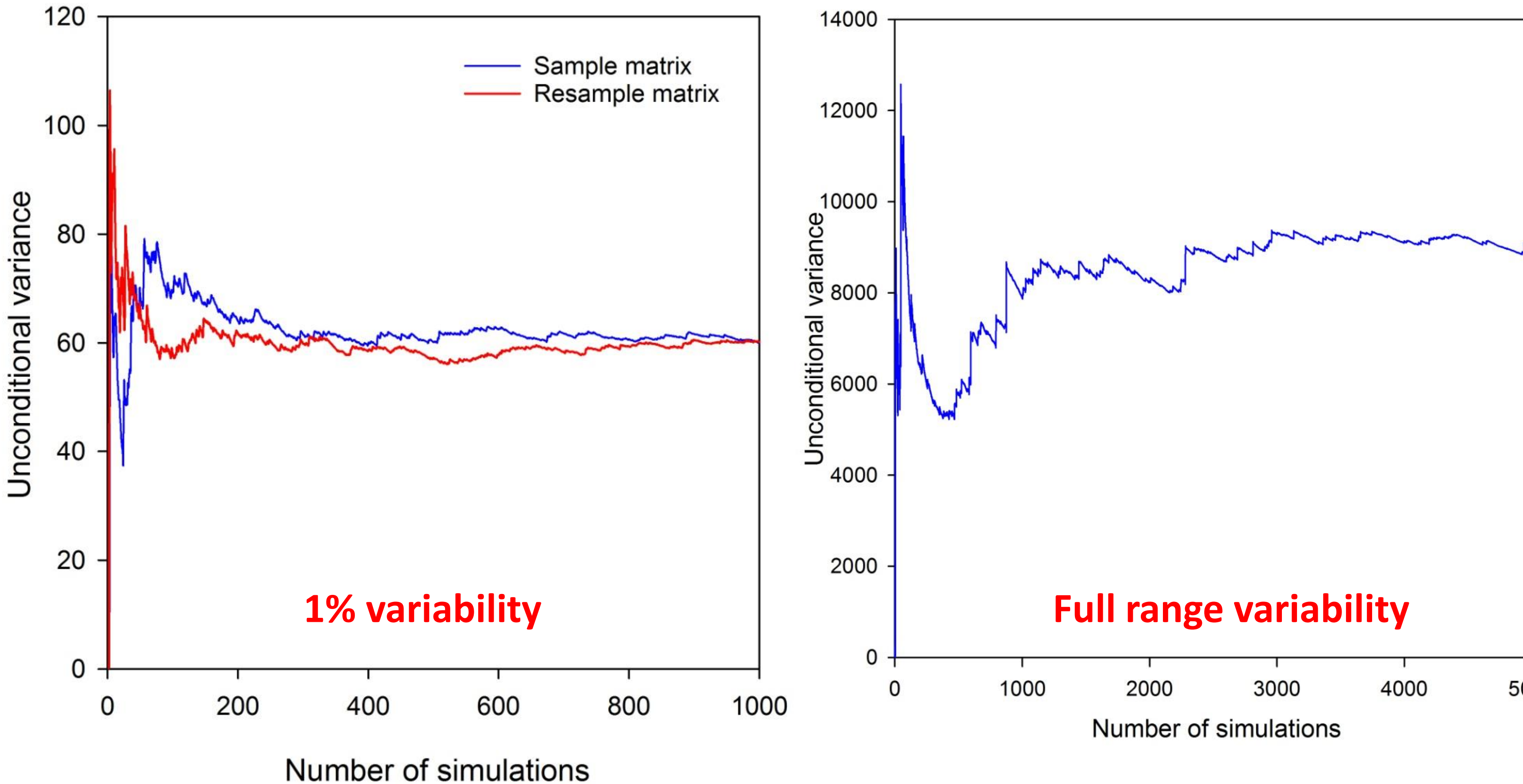

Fig 12. Convergence of model unconditional variance as a function of the number of simulations and input variability magnitude.

RESULTS: Preliminary Ranking of Variables

Variable	First order sensitivity (dimensionless)	Rank
Acfloor		
Acpit	0.002	
dp	**0.030**	3rd
Uo	**0.028**	4th
TAN		
Uf	0.002	
µmax		
Km	0.003	
Tfloor	0.002	
Tpit	0.001	
pHfloor	**0.168**	2nd
pHpit	**0.297**	1st
ufloor	0.002	
upit		
CF	0.002	
CE		
FR		
FE		
Sum	**0.538**	

Table 2. Partial results from the 'Global Sensitivity Analysis'

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Conclusions

1. The NH_3 emission model was successfully translated into a spreadsheet calculator

2. Implementation of management strategies to the NH_3 model is possible

3. GSA confirmed that model is largely sensitive to source pH and geometry

Thank you!

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