Merging and elevation of ventilation chimneys as method to reduce odour nuisance from pig production

Bjarne Bjerg

Department of Large animal Science, University of Copenhagen, DK1870 Frederiksberg C, Denmark

Email: bsb@sund.ku.dk

Abstract

Danish farmers that wish to establish or expand animal production facilities have to document that the expected odour nuisances at the neighbours are kept below certain thresholds. To do so the expected odour emission must be calculated from norm figures for expected odour emission from the wished production, and a certain atmospheric dispersion model (OLM) must be used to calculate whether the requirements are fulfilled. The farmers can choose to use the dispersion model for a calculation that takes into account individual preconditions as locations and design of ventilations chimneys. Alternatively they can use standard curves that gives the required distance to neighbours calculated at standardized preconditions. If the thresholds are not met, the farmer can include environmental technologies mentioned on a special list maintained by the environmental authorities. Currently biological air cleaners are the sole technology mentioned on the list that significantly can reduces the odour emission and the consequent required distance to the neighbours. An alternative to the relative expensive biological air cleaners is to release the air at a larger height which increases the dilution of odour before it reaches the neighbours. Low potentials found in elder analyses in relatively small herds might explain why the method is not already frequently used. Larger herds improve the possibilities to use larger chimneys and generate a larger vertical momentum which increases the effective release height.

The aim of this work is to enlighten the potential of merging and elevation of ventilation chimneys in order to reduce odour concentration around large pig production facilities. The analyses are based on an assumed facility with an installed ventilation capacity of 720000 m^3h^{-1}, which, in the reference case, is assumed to be released from 60 chimneys 0.7 m above the roof. Merging these chimneys to four or fewer 10 m high chimneys reduces the odour nuisance distance to the neighbours by 59-67 %.

1. Introduction

Danish farmers that wish to establish or expand animal production facilities have to document that the expected odour nuisances at the neighbours are kept below certain thresholds. To do so the expected odour emission must be calculated from norm figures for expected odour emission, and the OML atmospheric dispersion model (OML, 2016) must be used to calculate whether the requirements are fulfilled. The farmers can choose to use the dispersion model for a calculation that takes into account individual preconditions as locations and design of ventilations chimneys. Alternatively they can use standard curves that gives the required distance to neighbours calculated at standardized preconditions. If the thresholds are not met, the farmer can include environmental technologies mentioned on a special list maintained by the environmental authorities. Currently biological air cleaners are the sole technology mentioned on the list that significantly can reduces the odour emission and the consequent required distance to the neighbours. An alternative to the relative expensive biological air cleaners is to release the air at a larger height which increases the dilution of odour before it reaches the neighbours. Low potentials found in elder analyses in relatively small herds might explain why the method is not already frequently used. Larger herds improve the possibilities to use larger chimneys and generate a larger vertical momentum which increases the effective release height.

The aim of this work is to enlighten the potential of merging and elevation of ventilation chimneys in order to reduce odour concentration around large pig production facilities.

2. Materials and Methods

The OML-MULTI 6.0 model (OML, 2016) was used to calculate the minimum distances to neighbours for location of assumed a finisher pig units with 12 sections of 600 pig places. As reference case it was assumed that the installed ventilation capacity were release from 60 chimneys 0.7 m above the roof, see figure 1.

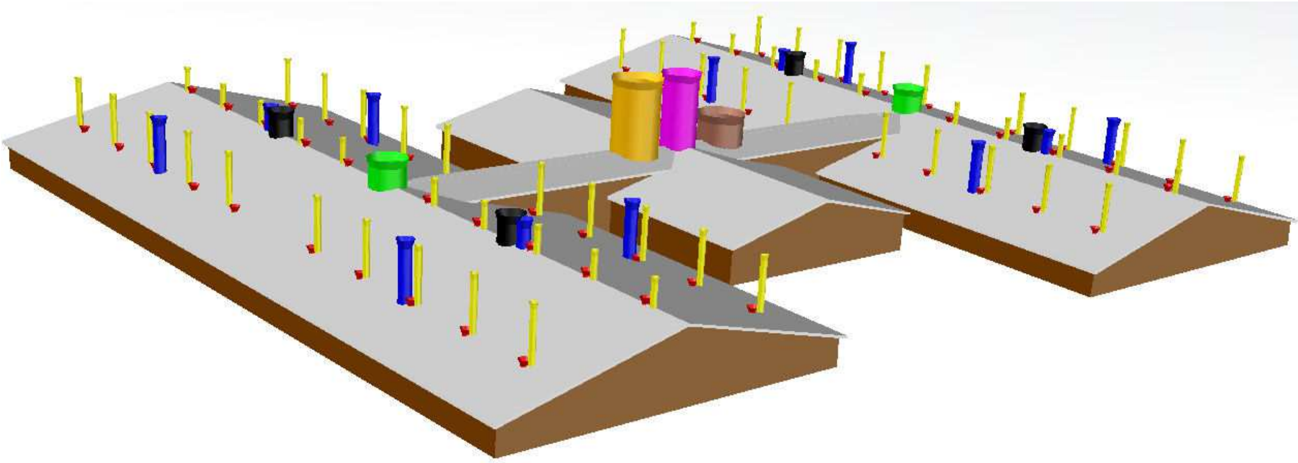

Figure 1. Assumed finisher pig unit with 12 sections or 600 places. Colours used for exhausts refers to the different configurations used in simulations and is explained in table 1

Table 1. Precondition for and results of conducted simulation. Locations of exhaust appear from figure 1.

Simulation (chimney configuration)	1	2	3	4	5	6	7	8	9
Number of exhausts	60	60	12	4	2	1	1	1	1
Height of exhausts, m	5 & 8	10	10	10	10	10	15	15	10
Capacity per exhaust, 1000 m^3h^{-1}	12	12	60	180	360	720	720	720	720
Diameter of exhaust, m	1.00	0.71	1.60	2.75	3.9	5.5	5.5	4.5	5.5
Velocity of exhaust, m s^{-1}	4.2	8.4	8.3	8.4	8.4	8.4	8.4	12.6	8.4
Exhaust temperature, °C	20	20	20	20	20	20	20	20	25
Thermal lifting, m^4 s^{-3}	0.4	1.4	1.8	5.3	10.7	21.3	21.3	21.3	32.4
Distance to nuisance level 5OU_e, m	1670	1340	880	680	620	590	550	550	550
Distance to nuisance level 7 OU_e, m	1310	1060	610	520	480	470	440	430	440
Distance to nuisance level 15 OU_e, m	750	390	340	270	270	280	260	240	260
Shortening of distance to 5 OU_e, %	-	20	47	59	63	65	67	67	67
Shortening of distance to 7 OU_e, %	-	19	53	60	63	64	66	67	66
Shortening of distance to 15 OU_e, %	-	48	55	64	64	63	65	68	65

The conducted calculations were based on following assumptions:

- 10 years of hourly weather data from Aalborg
- a total maximum ventilation capacity of 720 000 m^3 h^{-1},
- an overall odour emission at 226 800 OU_e s^{-1} (31.5 OU_e s^{-1} pig place^{-1} which corresponds to the Danish norm for a 70 kg pig kept on slatted or drained floor),
- ventilation capacity is expelled from 60, 12, 4, 2 or 1 exhausts (see Table 1),
- the expelled air and the odour emission is divided equally between the used exhausts,
- the temperature of expelled air 20 or 25 ° C
- 7. 5 m overall building height,
- no directional building height,
- that there are no differences in ground level, and
- terrain roughness of 0.1m (Agriculture including windbreaks or mixed nature)

The results of the calculations is presented as the distances required to ensure that the nuisance level do not exceeds the thresholds at three different categories of residential areas defined in Danish legislation. The defined residential areas and the corresponding nuisance levels are:

1. Urban areas - nuisance level of 5 OUe
2. Concentrated settlement in rural area - nuisance level of 7 OUe
3. Single housing in in rural area - nuisance level of 15 OUe

For all three categories of residential areas the mention nuisance level must be fulfilled in 99 % of the hours in the month were the estimated concentration is highest. The presented distance to the different nuisance levels mentioned in table 1 are average values for the 36 directions (each direction cover 10 degrees) that the OML model calculates.

3. Results and Discussion

Commonly used capacity, location, and air velocity of exhausts are assumed in simulations 1. (see red colours in Figure 1 and Table 1).

In simulation 2 is used fans of the same capacity, but the outlet height is increased from 5 or 8 to 10 m above ground and air velocity in the exhausts is doubled to 8.4 m s^{-1}. It appears from Table 1 that this alone shortens the distance to the nuisance level of 15 OU_e with 48 percent, while the effect is somewhat smaller in relation to nuisance levels of 5 and 7 OU_e.

In simulation 3 is the 5 exhaust per section is reduced to one per section and the effect is that the distance to all nuisance levels is reduced by about 50%.

Simulation 4 shows the merging of the exhausts from three sections shortens the distance to all nuisance levels by about 60%, and simulation 4 indicates that merging all air in two exhaust provides some additional effect with respect to interference levels 5 and 7 OU_e, so that the shortening of the distance to all nuisance levels reaches 63%. This effect is comparable to the effect of that can be obtained by a two stage biological air cleaning system mentioned on the list technologies maintain by the Danish environmental authorities.

The simulations 6, 7 and 8 show that there are additional, but quite small gains by collecting all the ventilation in a single exhaust, by increasing the exhaust height and by increasing the exhaust velocity.

Simulation 9 shows that the predicted temperature in the exhaust has only a limited impact on the required distances even though the calculated thermal lifting becomes larger.

4. Conclusions

Merging and elevation of ventilation chimneys can shorten the nuisance distance for odour by more than 60% in large pig herds.

Following relationships makes it relevant to used and developed the method:

- The method is likely economically competitive compared with biological air cleaning, which is the only approved alternative in Danish legislation that has a similar effect.
- The method is likely much more reliable than a biological air cleaning system.
- It is much easier to check whether the technology works than it is for a biological air cleaning system.
- The method is already accepted in Danish system for approval of livestock production.
- There are significant needs and potentials for developing the method in order to optimize the function and to minimize capital and operating costs.

References

OML, 2016. OML model – description. http://envs.au.dk/en/knowledge/air/models/oml/oml-model-description/ Accessed May17, 2016